QUALITY OF GROUND WATER IN CLARK COUNTY, WASHINGTON, 1988

by G. L. Turney

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CONVERSION TABLE

For the convenience of readers who may prefer to use metric units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.4047	hectare (ha)
	4.047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	259.9	hectare (ha)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

degree Celsius (°C) to degree Fahrenheit (°F): °F = 9/5 °C + 32

QUALITY OF GROUND WATER IN CLARK COUNTY, WASHINGTON, 1988

By G. L. Turney

ABSTRACT

Water samples were collected from 76 wells throughout Clark County, in southwest Washington, during April and May 1988. All samples were analyzed for concentrations of major ions, silica, nitrate, phosphorous, aluminum, iron, manganese, radon, and bacteria. Samples from 20 of the wells were also analyzed for concentrations of selected trace elements and organic compounds, including most of those covered by the U.S. Environmental Protection Agency (1) priority pollutant list, (2) Safe Drinking Water Act, and (3) National Primary Drinking Water Standards. The wells sampled were open to one of the geohydrologic units defined as part of a concurrent study. From top to bottom, the units are the unconsolidated sedimentary aquifer, Troutdale gravel aquifer, confining unit 1, Troutdale sandstone aquifer, confining unit 2, sand and gravel aquifer, and older rocks unit. Where the Troutdale sandstone aquifer is not present, the two confining units form a single undifferentiated fine-grained unit.

Dissolved-solids concentrations ranged from 12 to 245 milligrams per liter, with a median concentration of 132 milligrams per liter. Concentrations of dissolved solids generally increased along ground-water flow lines. The major dissolved constituents were calcium, bicarbonate, and silica, although concentrations of sodium were large in some samples from the older rocks unit. Most waters can be characterized as soft to moderately hard.

Values of pH, turbidity, and concentrations of iron and manganese did not meet U.S. Environmental Protection Agency Drinking Water Standards in several samples, but this was likely due to natural geohydrologic conditions. All other chemical constituents, including organic compounds, met established U.S. Environmental Protection Agency drinking water standards. The presence of total coliform and (or) fecal streptococci bacteria in samples from 26 wells was not confirmed on resampling, and likely was not due to regional conditions. No fecal coliform bacteria were detected.

Concentrations of nitrate as nitrogen exceeded 1.0 milligram per liter throughout the Vancouver urban area, and were as large as 6.7 milligrams per liter. Potential nitrate sources are septic systems and fertilizers. An analysis of limited historical data indicates that nitrate concentrations may be decreasing in the southwestern part of the county around the Vancouver urban area. A slight increase in nitrate concentrations was noted in rural areas. Nitrate concentrations correlated with sulfate concentrations ($r = 0.61$), indicating similar sources for the two.

Volatile organic compounds were present in samples from three wells, all in the Vancouver urban area. Compounds identified included tetrachloroethene, 1,1,1-trichloroethane, and other solvents. Trace amounts of volatile organic compounds were detected in samples from several other wells, but the concentrations were too close to analytical detection limits to ascertain if these compounds were present in the ground water. Atrazine was detected in a sample from one of the Vancouver area wells, and 2,4-D was detected in samples from two rural wells. No other organic compounds were detected.

Trace elements and radiochemical constituents were present only at small levels, indicating natural sources for these constituents.

INTRODUCTION

Ground water is the primary source of water for municipal, industrial, agricultural, and domestic use in Clark County, Washington. Because of this dependence, the Ground-Water Advisory Committee for Clark County, together with the Intergovernmental Resource Center (IRC) of Clark County, is developing a ground-water management plan under the Ground Water Management Area (GWMA) program. The GWMA program is administered by the State of Washington Department of Ecology (WDOE). As a part of developing the management plan, the GWMA program calls for studies of the physical and chemical characteristics of the geohydrologic system.

The U.S. Geological Survey entered into a cooperative agreement with the IRC to conduct two related ground-water studies of Clark County. One is to describe the geohydrologic framework (R. D. Swanson and others, U.S. Geological Survey, written commun., 1989) and flow system. The other is to describe the chemical characteristics of the ground water, within the framework defined in the first study. The latter study is the subject of this report.

Purpose and Scope

The purpose of this report is to define representative concentrations of inorganic and organic constituents in the ground water throughout Clark County and use those concentrations to determine the overall water quality. Concentrations of inorganic and organic constituents are compared with U.S. Environmental Protection Agency (USEPA) Drinking Water Standards where applicable. Variations in concentration as a function of area, depth, and geohydrologic unit are also discussed. Changes in concentration with time are considered where sufficient historical data exist. Concentrations as a function of regional flow are considered, but local variations are not defined because of the large scale of the study.

Approach

Seventy-six wells in Clark County (fig. 1) were sampled during April and May 1988. All samples were analyzed for concentrations of major ions, silica, nitrate, phosphate, aluminum, iron, manganese, radon, and bacteria. Field measurements of pH, specific conductance, temperature, and dissolved-oxygen concentration were also made at all sites. Samples from 20 of the 76 wells were analyzed for concentrations of selected dissolved trace elements and organic compounds. The specific elements and organic compounds included most of those in the USEPA (1) priority pollutant list (Federal Register, 1988), (2) Safe Drinking Water Act (U.S. Environmental Protection Agency, 1987b), and (3) National Primary Drinking Water Standards (U.S. Environmental Protection Agency, 1987a). Twenty-eight wells were resampled in July and August 1988 to verify previous bacteria results or to replace samples lost in the laboratory. The analytical data from all of the samples are presented in the tables in Appendix A.

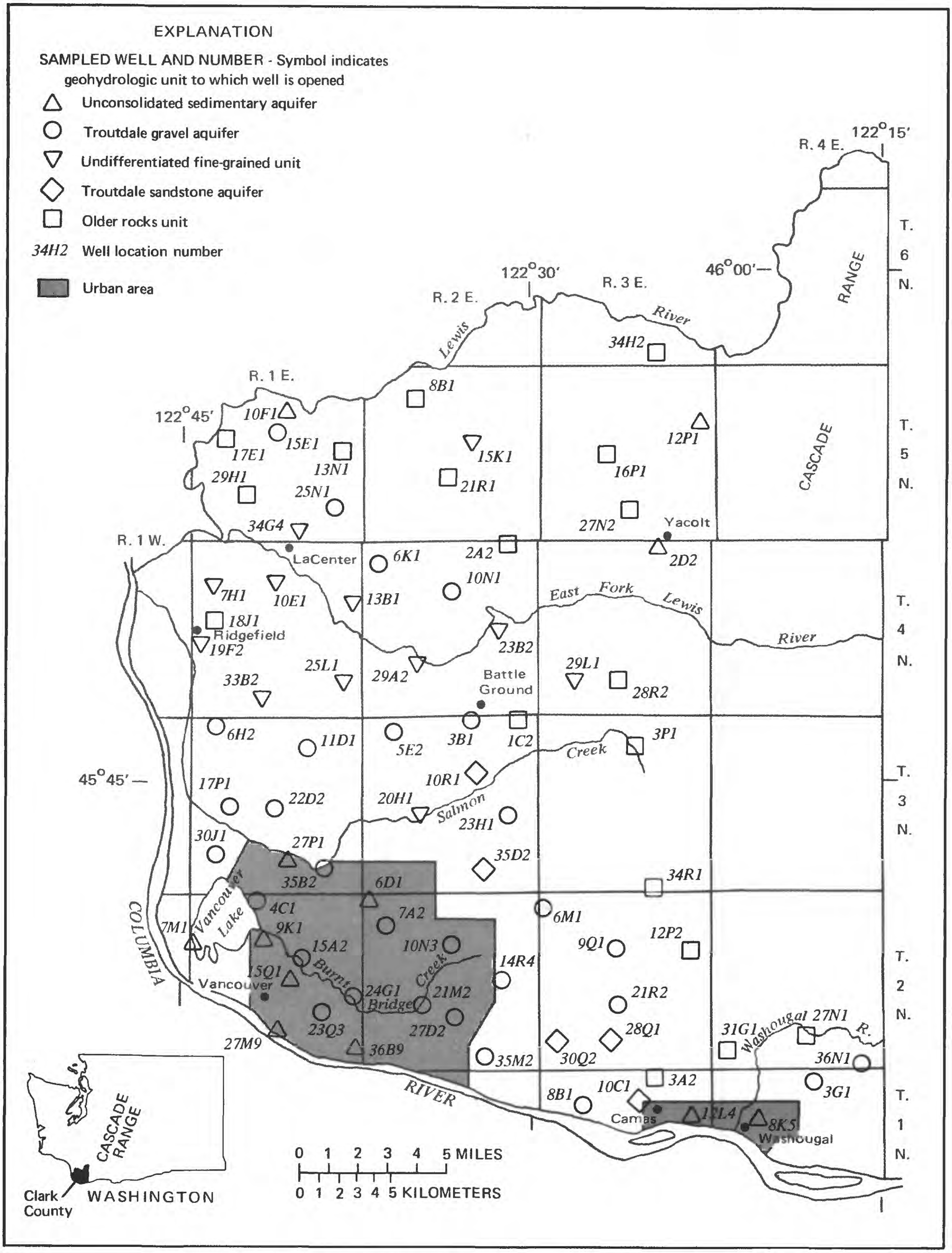

FIGURE 1.--Location of sampled wells in Clark County.

The results of the concurrent work on the geohydrology of the county (R. D. Swanson and others, U.S. Geological Survey, written commun., 1989) were used to identify the geohydrologic units to which each well was open. These data, in conjunction with regional flow data, aquifer characteristics, and land-use data, are used to help explain some of the spatial variability in ground-water quality.

Previous Studies and Historical Data

Mundorff (1964) conducted an extensive ground-water study of Clark County, but this work was limited primarily to a physical description of the geology and aquifer characteristics. Data from 12 samples from the southwestern part of the county provided the basis for a cursory discussion of ground-water quality. Likewise, a statewide study of ground-water quality by Van Denburgh and Santos (1965) included a general discussion of Clark County as part of a larger subdivision of the State. Ebbert and Payne (1985) included a section about Clark County in their discussion of the principal aquifers of southwest Washington. Although the data base from Ebbert and Payne (1985) contained information for more than 40 wells from Clark County for the period 1949-1989, it is of limited use in assessing present-day conditions because most of the data are now more than 10 years old. In all of these previous reports, only concentrations of inorganic constituents, usually common ions and a few trace metals, were determined. Concentrations of organic compounds were not determined.

State and local agencies, such as WDOE, the State of Washington Department of Social and Health Services (DSHS), and the Southwest Washington Health District, have extensive unpublished data bases. Generally, these data are obtained from the monitoring of public-supply wells and are collected to ensure compliance with drinking water standards. The samples are analyzed for concentrations of trace metals, nitrate, and bacteria. In March 1988, samples collected from wells in the city of Vancouver and Clark County Public Utilities District municipal water systems were analyzed by DSHS for concentrations of volatile organic compounds.

Most of the data from previous work are available from computer data bases. All of the U.S. Geological Survey data for this study and the previous studies mentioned reside in WATSTORE, a National data base maintained by the U.S. Geological Survey. Much of the unpublished monitoring data are in data bases kept by DSHS and WDOE, and there is some overlap between the two. The most comprehensive data base is STORET, maintained by the USEPA. It contains all of the data in WATSTORE and most of the monitoring data, including the WDOE data base. Access to these data bases can be obtained by contacting the appropriate agency. Data from previous work will be presented in this report only when they are pertinent to an interpretation.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in the State of Washington is based on the rectangular subdivision of public land, which indicates township, range, section, and 40-acre tract within the section. For example, in well number 02N/03E-12P02 (see figure 2), the part preceding the hyphen indicates the township and range (T.02 N., R.03 E.) north and east of the Willamette base line and meridian, respectively. The first number following the hyphen (12) indicates the section, and the letter (P) gives the 40-acre tract within that section. The last number (02) is the serial number of the well in that 40-acre tract. If a well has been deepened, the serial number is followed by the letter "D" and a number indicating the sequence of the deepening. For example, if 02N/03E-12P02 had been deepened twice, it would now be numbered 02N/03E-12P02D2.

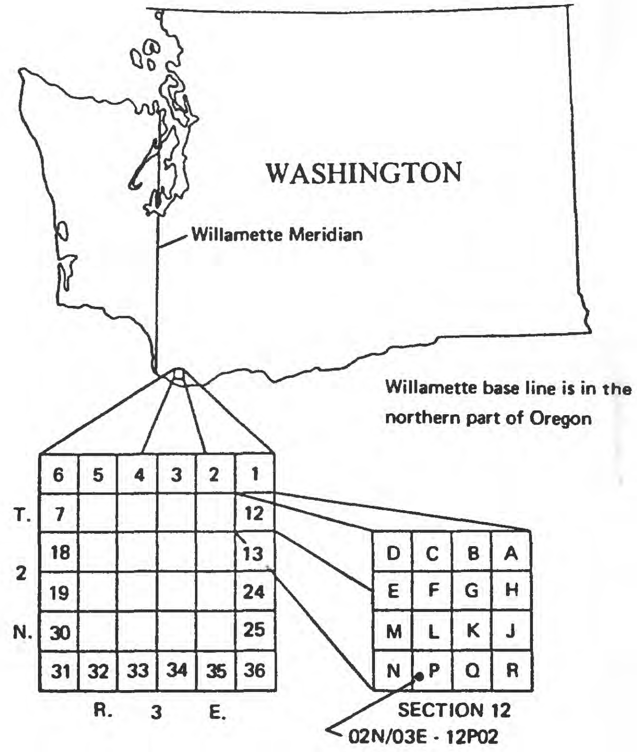

FIGURE 2.--Well-numbering system in Washington.

Acknowledgments

Appreciation is expressed to municipal and industrial employees and private well owners who allowed wells to be sampled. Their cooperation was essential to the study.

DESCRIPTION OF STUDY AREA

Clark County covers 627 square miles in southwestern Washington (fig. 1). The county's southern and western boundaries are the Columbia River, and the northern boundary is the Lewis River. The eastern boundary is the township/range grid line separating Ranges 4 East and 5 East. Along the Columbia River, much of the topography is alluvial flood plain, which gives way to a series of plains and benches extending from the northwest to the southeast part of the county. The foothills of the Cascade Range make up the northeastern third of the county. Major drainages of the county are the East Fork Lewis, Lewis, and Washougal Rivers and Salmon and Burnt Bridge Creeks, all of which are tributary to the Columbia River.

The major urban area of the county is the city of Vancouver (1985 population 42,760) and its suburbs, located in the southwestern part of the county. Other cities and towns include Camas, Washougal, Battle Ground, Ridgefield, LaCenter, and Yacolt (fig. 1). The total population of Clark County in 1985 was 203,400.

Annual precipitation in the county ranges from approximately 40 inches at Vancouver to 50 inches at Battle Ground and more than 100 inches in the Cascade foothills in the northeast. Approximately 75 percent of the precipitation occurs in the 6-month period from October through March (National Oceanic and Atmospheric Administration, 1982).

Geohydrologic Units

The original description of geohydrologic units for Clark County was done by Mundorff (1964). He described the area as a structural north-south basin in older consolidated rocks that has filled with a series of younger sedimentary deposits. R. D. Swanson and others (U.S. Geological Survey, written commun., 1989) recently identified and described several geohydrologic units and also have related the units to those used in other geohydrologic studies of Clark County. Detailed descriptions of these units as they occur in Oregon, just south of Clark County, were also presented by Hartford and McFarland (1989). This section summarizes Swanson's description of the geohydrologic units.

The geohydrologic units identified by R. D. Swanson and others (U.S. Geological Survey, written commun., 1989) are listed in table 1. From the surface down, these are the unconsolidated sedimentary aquifer, Troutdale gravel aquifer, confining unit 1, Troutdale sandstone aquifer, confining unit 2, sand and gravel aquifer, and older rocks unit. Where the Troutdale sandstone aquifer is not present, the confining units cannot be distinguished and form one unit, the undifferentiated fine-grained unit. All except the confining units are sufficiently permeable to be productive aquifers. In northern Clark County, even the undifferentiated fine-grained unit, or confining unit 1, can contain large amounts of permeable sand. The surficial occurrence of these units is shown in figure 3, and generalized geohydrologic sections of the county identifying the units are shown in figure 4. The units used in this study are compared in table 1 with those assigned by Mundorff (1964).

Table 1.--Correlation of geohydrologic-unit names in this study with those assigned by Mundorff (1964).

SYSTEM	SERIES	GEOHYDROLOGIC UNIT			
		Mundorff (1964)		This report (R.D. Swanson and others)	
Quaternary	Holocene	Alluvium		Unconsolidated Sedimentary Aquifer	
	Pleistocene	Terrace Deposits			
		Glacial Drift		Troutdale gravel aquifer	
		Boring Lava			
Tertiary	Pliocene	Troutdale Formation	Upper member		
			Lower member	Undifferentiated fine-grained unit	Confining Unit 1
					Troutdale Sandstone Aquifer
					Confining Unit 2
	?				Sand and gravel aquifer ?
	Miocene	Older consolidated rocks		Older rocks	
	Eocene				

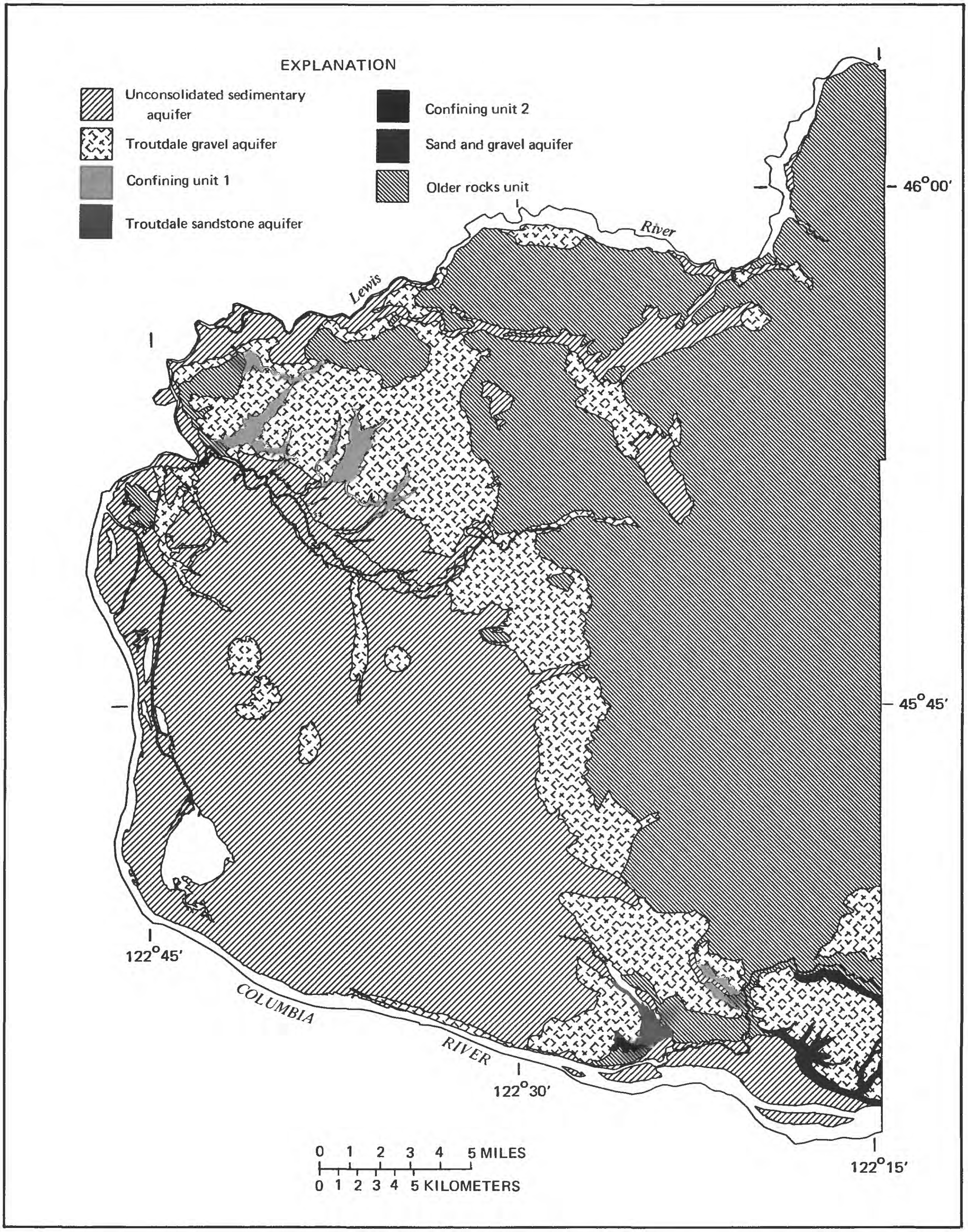

FIGURE 3.--Surficial geohydrologic units of Clark County (from R.D. Swanson and others, U.S. Geological Survey, written commun., 1989).

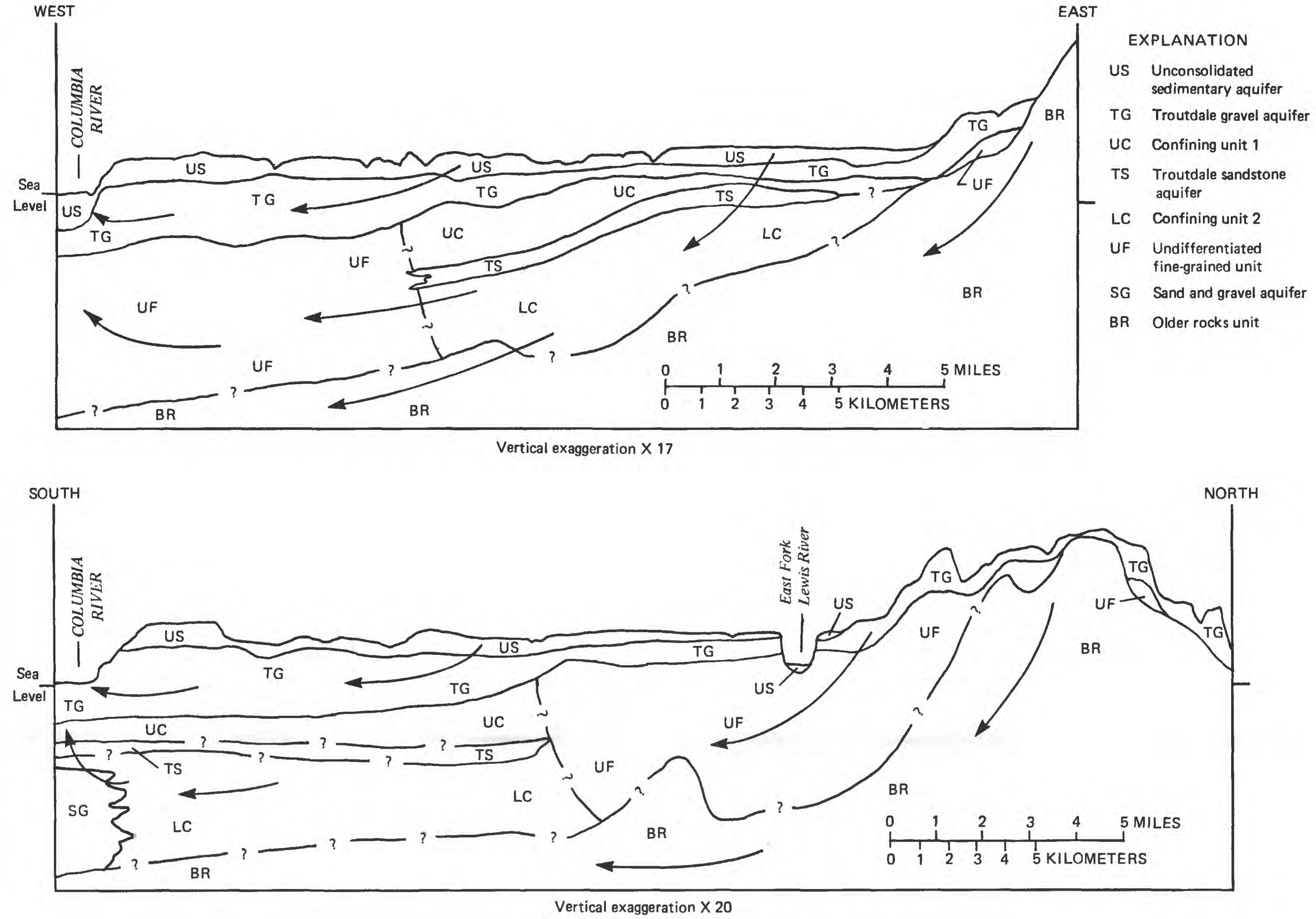

FIGURE 4.--Generalized geohydrologic sections through Clark County showing direction of ground-water flow. Adapted from W.D. McFarland, U.S. Geological Survey, written commun., 1988; and R.D. Swanson and others, U.S. Geological Survey, written commun., 1989.

The unconsolidated sedimentary aquifer is composed of a series of alluvial deposits from the Columbia River and other surface waters. The aquifer is contained mostly in late Pleistocene catastrophic flood deposits that mantle much of the county and Holocene Columbia River alluvium that fills the late Pleistocene Columbia River channel. This unit is as much as 300 feet thick and is the surficial unit throughout the southwestern third of the county (fig. 3), where it is an important water source. However, in some areas these unconsolidated sediments may be above the water table and are unsaturated. Similar sand and gravel alluvial deposits are found in stream channels in the northeastern part of the county, and are a source of ground water there also.

The Troutdale gravel aquifer is the primary source of ground water in Clark County. The aquifer is composed of several geologic units that are primarily poorly to moderately cemented conglomerate and sandy conglomerate (Upper member of the Troutdale Formation), but it also includes thick accumulations of lavas (Boring Lavas) and mantling soil horizons (table 1). The Troutdale gravel aquifer is as much as 400 feet thick and occurs in the plains and benches of the county located in the west and south. The aquifer occurs in rocks of Pliocene to early Pleistocene age and is exposed in a band approximately 2 to 5 miles wide trending through the center of the county from the northwest to the southeast (fig. 3). Because this unit is so productive, many wells are completed in it, but few wells penetrate it to the bottom.

Confining unit 1 consists of olive-grey to grey-brown silt, medium- to fine-grained quartzose sands, and clay. The unit consists of rocks of Pliocene age (table 1) and underlies the western half and southern edge of Clark County, with extensive outcropping in the northwest (fig. 3). In general, it is not a major water source, but in the northwestern part of the county, sand lenses in the unit are sufficiently productive to supply domestic wells.

The Troutdale sandstone aquifer consists of black basaltic glass (sideromelane), with local silty-clay lenses. The lower part of the unit also contains quartzite-bearing basalt conglomerate. This aquifer is within the Troutdale Formation, which is of Pliocene age. The aquifer averages 100 feet in thickness and occurs beneath the upper confining unit in the central and southern parts of the county, but is not found in the northern part of the county. It is exposed in the southeastern part of the county, where it is an important water source. It also has the potential to be developed more extensively where it exists beneath younger units.

Confining unit 2 is predominantly greyish-olive clay with minor amounts of silt and thin lenses of fine to medium basaltic sand. In some areas, claystone occurs near the bottom of the unit. This aquifer is within rocks of Pliocene age (table 1) and underlies the western half and southern edge of the county, but is exposed only in a small part of the southeast. The unit is as much as 100 feet thick, but is a productive water source only where a sand lens is tapped.

The confining units are indistinguishable when the Troutdale sandstone aquifer is absent. The combined units, therefore, are referred to as the undifferentiated fine-grained unit (table 1), which has the characteristics of the two confining units. By definition, then, confining units 1 and 2 occur only in the southern half of the county where the Troutdale sandstone aquifer occurs. In the northwestern part of the county, the two confining units become the undifferentiated fine-grained unit (see fig. 4).

The sand and gravel aquifer consists mostly of vitric basaltic, quartzose and micaceous sands and gravels grading from coarse to fine with depth. Minor clay and silt lenses also occur in the unit. The sand and gravel aquifer occurs in the extreme southern part of the county and is exposed in the southeast. The aquifer is within rocks of upper Miocene to Pliocene age (table 1) and is more than 300 feet thick in places. Although the unit is a good aquifer, it is seldom used because of the productivity of the aquifers above it.

The older rocks unit consists of consolidated rocks of Eocene to Miocene age (table 1). The rocks were derived from volcanic activity alternating with marine and nonmarine sediment deposition. The older rocks unit is mostly basalt and andesite. It occurs throughout the county and is the predominant surficial unit in the hilly northern and eastern parts of the county (fig. 3). In southwestern Clark County, the older rocks unit is overlain by several hundred feet of younger deposits. However, in the east and north, where these younger deposits are thin or absent, it is generally an important source of water.

Ground-Water Flow System

Regional ground-water flow in the Troutdale gravel aquifer, as estimated from ground-water-elevation contours, is towards the Columbia, Lewis, and East Fork Lewis Rivers (fig. 5). This is generally from the northeast to the southwest, except where influenced by these rivers. The contours shown in figure 5 are adapted from Mundorff (1964) and from the current (1988) geohydrologic study (W. McFarland, U.S. Geological Survey, written commun., 1988). Contours over most of the area north of the East Fork Lewis River are not shown because the hilly topography causes the water levels to vary greatly over short distances. Horizontal flow is perpendicular to the contours, which generally parallel the major rivers. Recharge occurs throughout the county, but is probably greatest in the north and east where there is more precipitation. Regional vertical flow is downward (fig. 4), except near the Columbia River, where flow is upward, toward the river. Local variations in flow may be considerable due to discharge to surface waters and extensive pumping of ground water by municipal and industrial users.

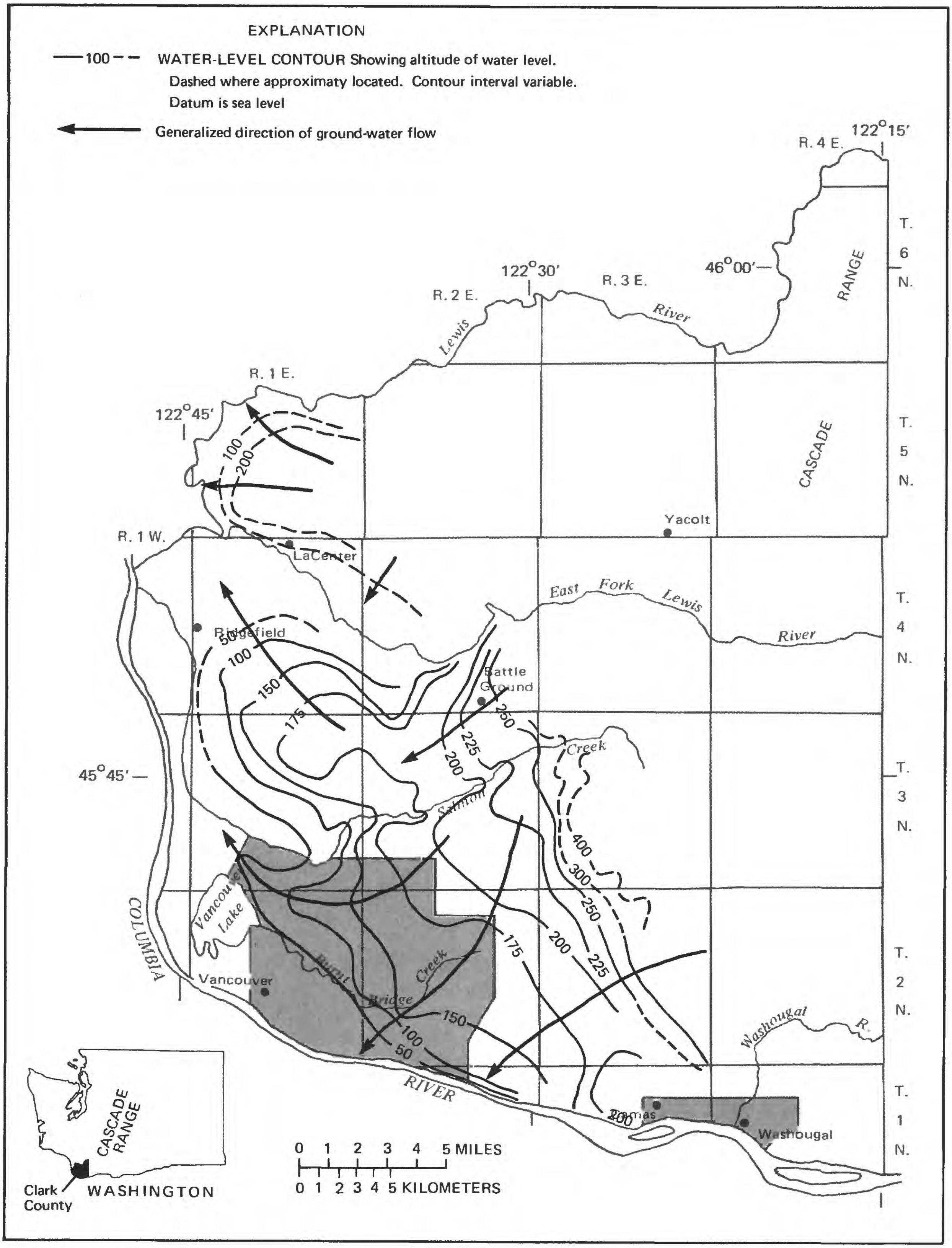

FIGURE 5.--Water-level contours and generalized direction of ground-water flow in the Troutdale gravel aquifer in Clark County. Modified from Mundorff (1964) and W.D. McFarland (U.S. Geological Survey written commun., 1988). Contours north of the East Fork Lewis River are uncertain because of complexity.

METHODS

Standard U.S. Geological Survey sampling and analytical methods were used throughout the study. GWMA guidelines, as outlined by Carey (1986), were also followed where applicable. The methods used, especially the sampling and quality-assurance procedures, are outlined in detail in the Quality Assurance Plan for Ground Water Quality of Clark County, Washington (G.L. Turney, U.S. Geological Survey, written commun., 1986), an unpublished document for project use. This section presents an overview of the more important methods.

Well Selection

The wells sampled in this study (fig. 1) had been inventoried previously as part of the geohydrologic study. These wells are used primarily for domestic or municipal purposes, but a few are used for agricultural or industrial supplies. They were selected to provide an areally uniform distribution and a representative sampling of the geohydrologic units. Wells open to more than one geohydrologic unit were not selected. (Two of the sampled wells later were determined to be open to two units. Because each well was open mostly to one unit, that unit was assigned to the well, but the second unit is identified in footnotes in the tables in Appendix A.) Areas of known regional ground-water-quality problems, such as elevated nitrate concentrations in the Vancouver area, were also considered in the selection process. The subset of 20 wells from which samples were analyzed for concentrations of trace elements and organic compounds was selected using generally the same criteria. For these 20 wells, priority was given to sampling municipal wells because of easy access and because the IRC needed data on water supplies serving large numbers of people.

Occasionally, the selected well could not be sampled, most commonly because of disconnected power supplies (especially for wells used for seasonal irrigation) or inadequate plumbing fixtures for collecting a proper sample. A substitute was selected using the same criteria. The original well distribution was not altered, either areally or geologically.

Of the wells sampled, 12 are finished in the unconsolidated sedimentary aquifer, 29 in the Troutdale gravel aquifer, 12 in the undifferentiated fine-grained unit, 5 in the Troutdale sandstone aquifer, and 18 in the older rocks unit. Because of the relation between confining unit 1 and the undifferentiated fine-grained unit, all wells finished in these two units are considered in this study as being finished in the undifferentiated fine-grained unit. None of the sampled wells was assigned to confining unit 2 or the sand and gravel aquifer.

Sampling Procedures

Water samples were collected from a plumbing tap in the well's distribution system, as close to the wellhead as possible. Where feasible, samples for inorganic analysis were collected from a tap ahead of any holding tank in the system. Samples for organic analysis always were collected ahead of holding tanks. All samples were collected prior to any water treatment, such as chlorination, fluoridation, or softening. Sample water was fed from the tap through nylon tubing to a stainless-steel flow-directing manifold mounted in the field vehicle. A schematic of the system is shown in figure 6. At a flow chamber pH, temperature, and dissolved-oxygen concentration were monitored continuously. When readings for these constituents were constant for 10 minutes, raw and filtered inorganic samples were collected from the appropriate manifold outlet. This meant that the well had been pumped for 15 to 45 minutes, depending upon the individual well yield. Finally, samples for organic and bacteria analysis were collected directly from the tap.

After collection, samples were treated and preserved according to standard Geological Survey procedures (Feltz and others, 1985). Samples requiring laboratory analysis were sent to the appropriate laboratory either by courier or by first-class mail at the end of the day. All sampling equipment was rinsed and cleaned as appropriate before samples were collected at the next site.

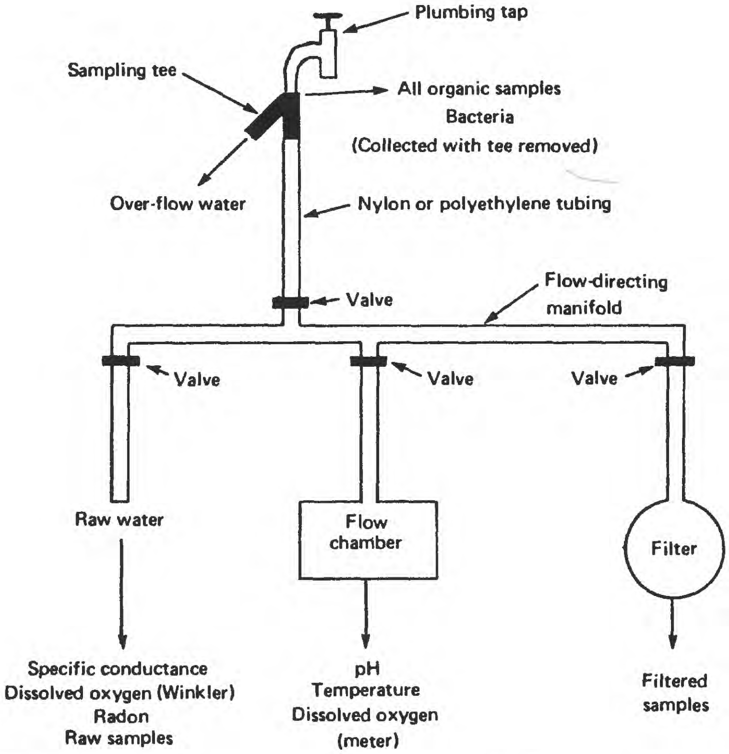

FIGURE 6.--Ground-water-sampling system with flow-directing manifold.

Analytical Procedures

Several properties and constituent concentrations were determined in the field. Values of pH, specific conductance, dissolved-oxygen concentration, and temperature were determined onsite using procedures outlined by Wood (1981). Dissolved-oxygen concentrations were determined using a meter, and concentrations of 1.0 mg/L (milligrams per liter) or less were verified in the field using the Winkler titration method (American Public Health Association and others, 1985; Wood, 1981). Bicarbonate and carbonate concentrations were determined onsite using the incremental titration method described by Wood (1981) and Pickering (U.S. Geological Survey, written commun., 1981). Samples were analyzed in the field for concentrations of total and fecal coliform bacteria and fecal streptococci bacteria using membrane filtration methods outlined by Greeson and others (1977).

Most laboratory analyses were done by the U.S. Geological Survey's National Water Quality Laboratory (NWQL) in Arvada, Colo. Dissolved concentrations were determined for all inorganic constituents, and total concentrations were determined for all organic compounds. Analytical procedures used at the NWQL are described by Fishman and Friedman (1985), Thatcher and others (1977), and Wershaw and others (1987). Determinations of turbidity were made at the U.S. Geological Survey's Tacoma office field support-unit facility, using procedures outlined by Fishman and Friedman (1985). Concentrations of selected pesticides (including selected triazines and chlorophenoxy herbicides) in some samples were determined by a private laboratory under contract to the IRC. The analysis for these selected pesticides was not part of the U.S. Geological Survey's cooperative agreement with the IRC.

Quality Assurance

Accurate field measurements of pH, specific conductance, dissolved-oxygen concentrations, and temperature were obtained by frequent (at least daily) calibration of meters with known standards. Field analyses of concentrations of bacteria, bicarbonate, and carbonate were performed in duplicate for one in every 15 wells sampled. Alkalinity also was calculated from the bicarbonate and carbonate values and compared to the alkalinity value determined by the NWQL.

Samples for analysis at the laboratories were collected in duplicate on a random basis. One duplicate sample for inorganic analysis was collected for every 15 wells sampled, and one duplicate sample for organic analysis was collected for every 10 wells sampled. Blank samples, prepared from deionized water, were analyzed at the same frequencies. Duplicates and blanks were prepared in the same manner as ordinary ground-water samples and were submitted to the laboratories disguised as ground-water samples.

No standards or spiked samples were submitted from the field to the laboratories, but standards for most inorganic constituents are inserted into the sample stream at the NWQL as blind samples. Appropriate standards are spiked into each sample for organic analysis to determine percent recoveries.

Standard quality-assurance procedures were used at the NWQL. Resulting data were reviewed by laboratory personnel, then released to the local U.S. Geological Survey district office by computerized data transfer. The data are further reviewed by district personnel in the context of the hydrologic setting. Computer programs are used to assist in all stages of the reviews. Additional details of laboratory quality-assurance procedures and of data review are discussed in the project quality-assurance plan referred to earlier on page 14 (G. L. Turney, U.S. Geological Survey, written commun., 1988) and by Friedman and Erdmann (1982). A detailed review of the quality-assurance data for this project is included in Appendix B of this report.

QUALITY OF GROUND WATER IN CLARK COUNTY

Ground-water quality is discussed in two sections. The first is descriptive and relates statistical summaries of the data to USEPA drinking water standards (U.S. Environmental Protection Agency, 1976; 1977; 1987a). Primary drinking water standards identified in the tables of this section are legally required and enforceable by appropriate regulating agencies. Secondary standards identified in the tables are considered to be guidelines and are not legally enforceable. The second ground-water-quality section of this report relates observed spatial variations in constituent concentration to flow, geohydrologic unit, and causal factors, where possible. All supporting basic data are presented in Appendix A.

Data Summaries and Drinking Water Standards

Water from several wells did not meet existing USEPA drinking water standards: 7 for pH, 18 for turbidity, 3 for iron concentrations, 13 for manganese concentrations, and 11 for total coliform bacteria concentrations. Locations of the wells from which these samples were collected are shown in figures 7 and 8. Concentrations of all other inorganic, radiochemical, and organic constituents met applicable USEPA drinking water standards.

Common Constituents

The median concentration of dissolved solids in Clark County ground water was 132 mg/L, small by most standards. Even the maximum concentration of 245 mg/L was less than half the USEPA drinking water standard of 500 mg/L. The minimum dissolved-solids concentration was 12 mg/L. Minimum, median, and maximum concentrations of dissolved solids and other common constituents are shown in table 2.

The predominant minerals contributing to the dissolved solids are calcium, bicarbonate, and silica, typical of western Washington ground water (Ebbert and Payne, 1985; Turney, 1986a). As can be seen by the maximum values (table 2), magnesium, sodium, carbonate, sulfate, and chloride were also major constituents in some samples, but overall (median) concentrations were small compared with calcium, bicarbonate, and silica. Concentrations of potassium, fluoride, nitrate, phosphorus, aluminum, iron, and manganese were generally too small to be considered major components of the water chemistry.

Most water samples were classified as soft or moderately hard, as defined by the following scheme (Hem, 1985):

Description	Hardness range (mg/L of $CaCO_3$)	Number of samples
Soft	0-60	32
Moderately hard	61-120	37
Hard	121-180	6
Very hard	greater than 180	1

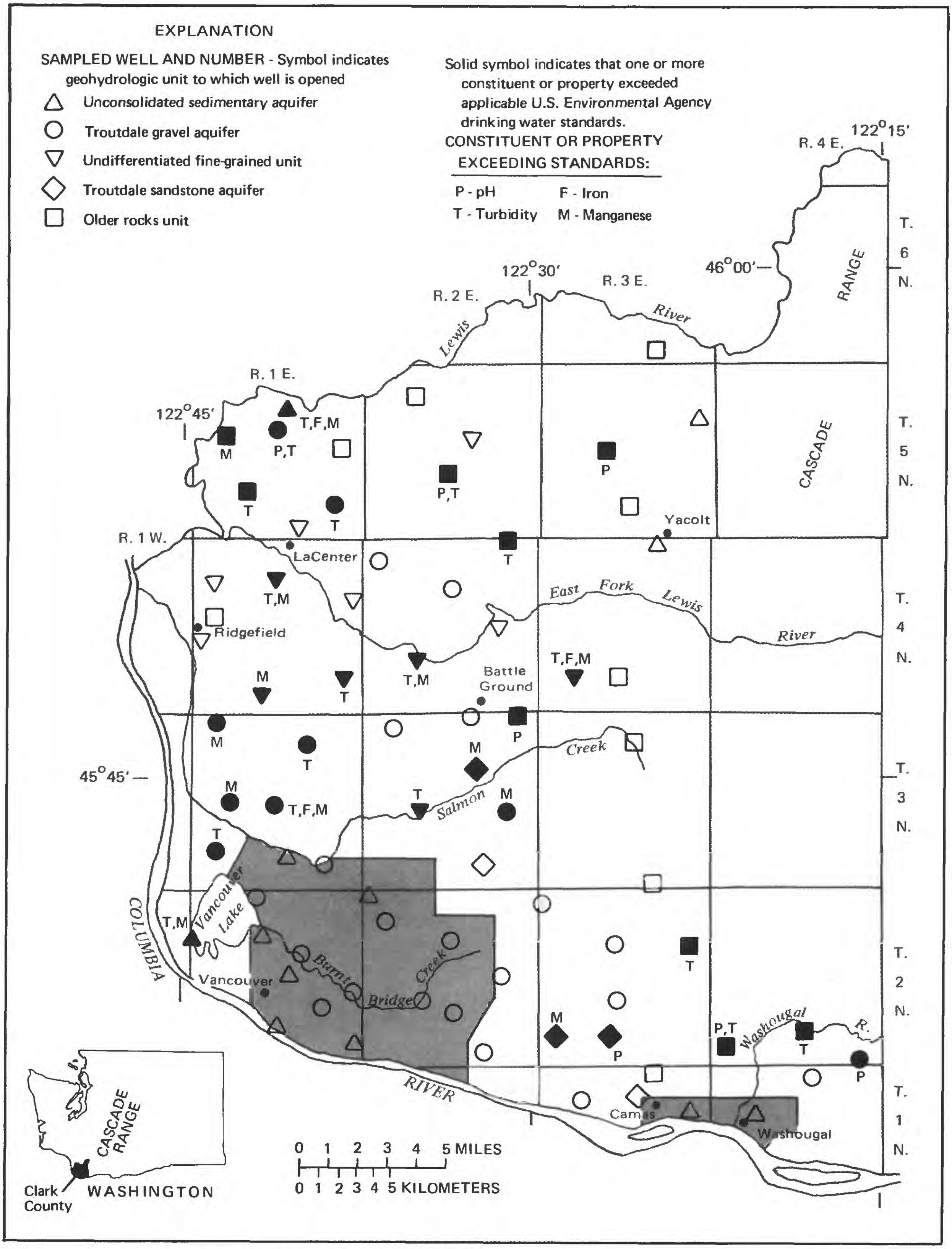

FIGURE 7.--Wells where samples analyzed for pH, turbidity, iron, and manganese did not meet U.S. Environmental Protection Agency drinking water standards.

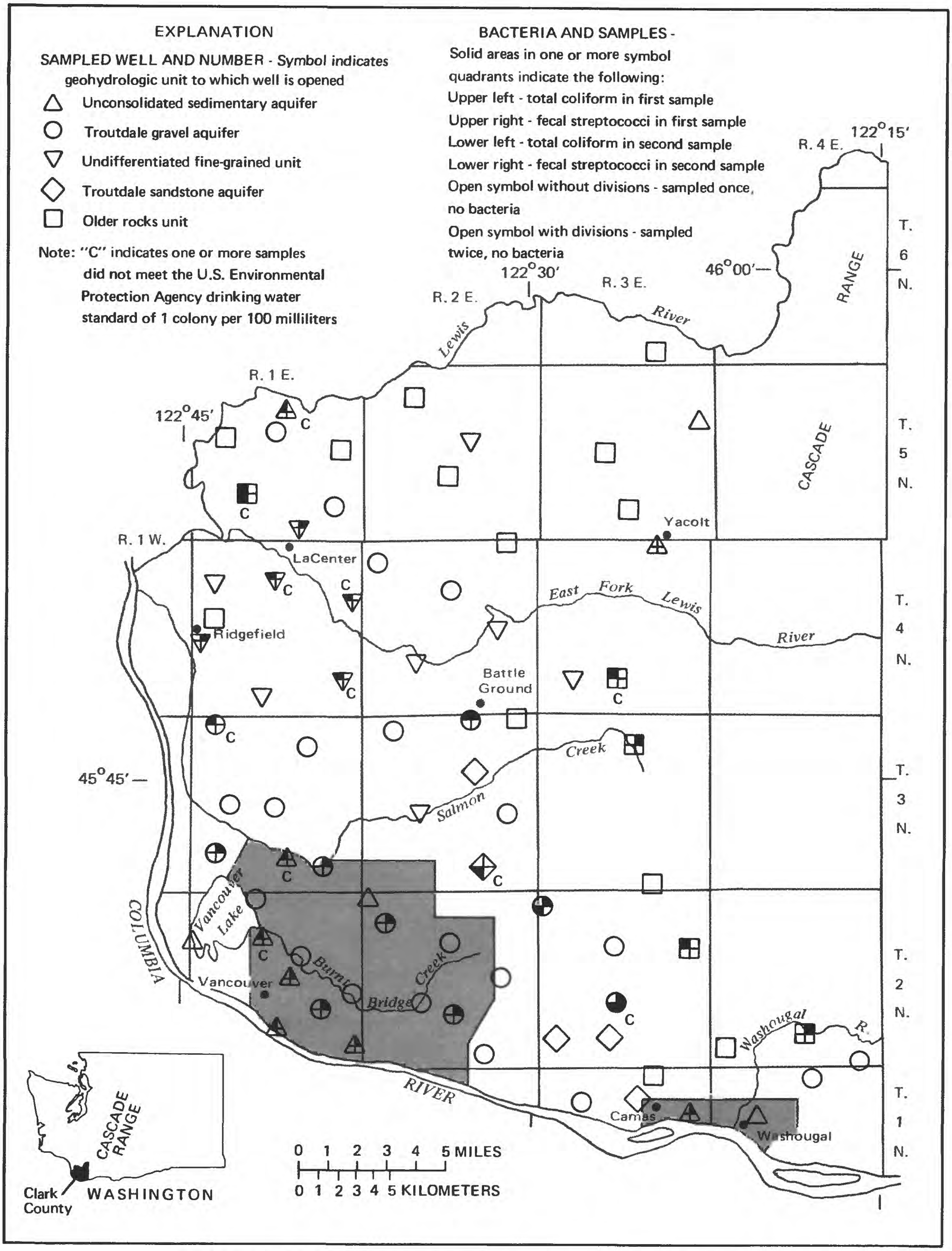

FIGURE 8.--Wells where one or more samples contained bacteria, and wells where concentrations of total coliform bacteria did not meet the U.S. Environmental Protection Agency drinking water standard.

Table 2.--Summary of values and concentrations of common constituents

[Concentrations in milligrams per liter (mg/L) unless otherwise noted. All are dissolved concentrations; μS/cm, microsiemens per centimeter at 25 degrees Celsius; NTU, nephelometric turbidity units; μg/L, micrograms per liter; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Constituent	Concentrations Minimum	Concentrations Median	Concentrations Maximum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
Specific conductance (μS/cm)	14	180	438	--	76	--
pH (standard units)	5.7	7.1	9.5	6.5 to 8.5*	76	7
Dissolved oxygen	.0	5.0	10.4	--	76	--
Turbidity (NTU)	.10	.30	75	1.0	76	18
Hardness as $CaCO_3$	3.0	73	190	--	76	--
Calcium	.57	17	52	--	76	--
Magnesium	.02	7.3	15	--	76	--
Sodium	1.1	7.6	70	--	76	--
Potassium	.10	1.8	6.6	--	76	--
Bicarbonate	6.0	97	247	--	76	--
Carbonate	0	0	22	--	76	--
Alkalinity as $CaCO_3$ (Field)	5.0	83	203	--	76	--
Sulfate	<.20	1.6	29	250*	76	0
Chloride	1.1	2.6	110	250*	76	0
Fluoride	.10	.20	2.0	4.0, 2.0*	76	0
Silica	8.4	47	68	--	76	--
Dissolved solids	12	132	245	500*	75	0
Nitrate	<.10	.16	6.7	10	76	0
Phosphorus	<.010	.070	.33	--	76	--
Aluminum (μg/L)	<10	<10	50	--	76	--
Iron (μg/L)	<3	5	7,700	*300	76	3
Manganese (μg/L)	<1	2	690	*50	76	13

[a] Primary drinking water standard unless noted with an asterisk, in which case the figure is a secondary drinking water standard.

Hardness is calculated from the concentrations of calcium and magnesium. The most familiar effect of increased hardness is a decreased production of lather from a given amount of soap introduced into the water.

The median pH value measured was 7.1 (table 2), but the pH of four samples was greater than the USEPA maximum value of 8.5, and the pH of three samples was less than the USEPA minimum value of 6.5. The primary concerns about water with pH values outside the recommended range are corrosion of plumbing fixtures and effects on aquatic life. Although such water may need to be treated for some specialized uses, it is generally not a human health concern. The pH values that did not meet standards probably are caused by natural processes--geochemical reactions that increase pH (discussed later) or low residence time, usually in recharge areas, where the low pH of precipitation is a factor.

There were 18 samples in which turbidity values were larger than 1.0 NTU (nephelometric turbidity units), the USEPA drinking water standard. The excessive turbidity was generally due to fine suspended aquifer material, most commonly a reddish material that was probably naturally occurring iron oxide. In several samples, increased turbidity was due, in part, to the presence of filamentous bacteria. These bacteria almost always occurred in conjunction with the fine iron oxide. Excessive turbidity is not necessarily a health problem, but it interferes with the effectiveness of chlorination and is esthetically undesirable.

All nitrate concentrations were smaller than the drinking water standard of 10 mg/L as nitrogen (N), and the median concentration of 0.16 mg/L (table 2) implies that overall nitrate concentrations are small. This is consistent with results of other studies in western Washington (Ebbert and Payne, 1985; Turney, 1986a). However, nitrate concentrations in samples from 20 wells were greater than 1.0 mg/L, indicating potential contamination. The presence of nitrates in concentrations as large as 6.7 mg/L (table 2) is certainly of concern. The actual analysis included both nitrite and nitrate; however, nitrite concentrations in these types of waters are usually small (National Research Council, 1978); therefore, the determined value is considered to be all nitrate. The areal distribution of nitrate concentrations will be discussed later on page 39.

Median iron and median manganese concentrations were small, 5 and 2 μg/L (micrograms per liter), respectively (table 2). However, iron concentrations in 3 samples and manganese concentrations in 13 samples were larger than USEPA drinking water standards. The maximum concentrations were more than an order of magnitude greater than the standards. The standards are based on esthetic considerations such as taste, odor, color, and staining of plumbing fixtures. These larger concentrations usually are due to localized geochemical processes in the ground water (discussed on page 41), and are common in western Washington (Turney, 1986a).

All other common constituents met applicable drinking water standards. One sample contained fluoride at a concentration of 2.0 mg/L, which is at, but does not exceed, the USEPA secondary drinking water standard.

Bacteria

Median concentrations of total coliform, fecal coliform, and fecal streptococci bacteria were all less than 1 colony per 100 milliliters (table 3). Bacteria were present in 26 samples (fig. 8). Total coliform were present in 11 samples, fecal streptococci in 14 samples, and both in 1 sample. None of the samples contained fecal coliform. All three bacteria are indicator bacteria, meaning they are not pathogenic, but occur in conjunction with pathogenic bacteria. However, fecal coliform are the only bacteria of the three for which a quantitative relation with a pathogen (salmonellae) has been derived (Geldreich and Van Donsel, 1970). To verify the original results, the 26 wells with samples containing bacteria were resampled in July and August and analyzed for bacteria, along with 2 selected wells from which the original samples did not contain bacteria. Only 4 of the 28 samples in

Table 3.--Summary of concentrations of bacteria

[--, no U.S. Environmental Protection Agency (USEPA) drinking water standard]

	Concentrations, in colonies per 100 milliliters					
Bacteria type	Minimum	Median	Maximum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
Total coliform	<1	<1	150	[b]1	76	[c]11
Fecal coliform	<1	<1	<1	--	76	--
Fecal streptococci	<1	<1	>200	--	76	--

[a] Primary drinking water standard.

[b] Standard is based on a monthly average of several samples collected at a prescribed schedule. Individual samples may exceed the standard.

[c] This figure is based on only one sample in a given month, and may not be representative of results from multiple samplings in a given month.

this second set contained any bacteria, and one of these was from a well that did not orginally contain bacteria (fig. 8). Like the first set of samples, none of the second set contained fecal coliform bacteria. The data from all samples are included in Appendix A.

Using both sample sets, 11 wells had samples where total coliform concentrations did not meet the USEPA standard of 1 colony per 100 milliliters (fig. 8). This is somewhat misleading because the standard is based on an average of multiple samples, and any one sample may exceed the standard. No standard exists for fecal coliform or fecal streptococci bacteria.

There is no clear hydrologic explanation for the occurrences of the bacteria in ground water. Quality-assurance data, especially field blanks, do not indicate a procedural problem. Possible sources include natural bacteria in the soil (Pelczar and others, 1977) or contamination of individual plumbing systems. Poor well construction may be a factor. An analytical problem may be the growth of noncoliform or nonfecal streptococci bacteria on the media, but this still implies the presence of bacteria in the water. The inconsistency between sampling sets may be the result of seasonal fluctuations. In any case, the results appear to be due to isolated conditions affecting individual wells, rather than any regional hydrologic characteristics.

Trace Elements

Concentrations of trace elements, when detected at all, were small (table 4). Even maximum concentrations were much smaller than applicable USEPA drinking water standards. When present, most trace elements were at concentrations consistent with natural levels (Hem, 1985). Slightly elevated concentrations of zinc and copper might be due to contamination from well plumbing systems.

Table 4.--Summary of concentrations of trace elements and cyanide

[Concentrations in micrograms per liter unless otherwise noted. All are dissolved concentrations; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Element	Concentrations			USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
	Minimum	Median	Maximum			
Antimony	<1	<1	13	--	20	--
Arsenic	<1	1	4	50	20	0
Barium	<2	7	30	1,000	20	0
Beryllium	<.5	<.5	<.5	--	20	--
Boron	<10	<10	40	--	20	--
Cadmium	<1	<1	<1	10	20	0
Chromium	<1	<1	3	50	20	0
Copper	<1	2	18	1,000*	20	0
Lead	<5	<5	<5	50	20	0
Mercury	<.1	<.1	.1	2	20	0
Molybdenum	<1	<1	3	--	20	--
Nickel	<1	1	4	--	20	--
Selenium	<1	<1	1	10	20	0
Silver	<1	<1	1	50	20	0
Thallium	<1	<1	<1	--	20	--
Vanadium	2	10	23	--	20	--
Zinc	<3	10	170	5,000*	20	0
Cyanide (milligrams per liter)	<.01	<.01	<.01	--	20	--

[a] Primary drinking water standard, unless noted with an asterisk, in which case the figure is a secondary drinking water standard.

Radiochemical Constituents

Median and maximum concentrations of all radiochemical constituents are much smaller than any applicable USEPA drinking water standards (table 5). All concentrations were in the range of natural systems (Hem, 1985). Because no major anthropogenic sources of radiochemical contamination are known to exist in Clark County, these concentrations appear to be due to natural sources.

Table 5.--Summary of concentrations of radiochemical constituents

[All are dissolved concentrations; µg/L, micrograms per liter; pCi/L, picocuries per liter; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Constituent	Concentrations Minimum	Concentrations Median	Concentrations Maximum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
Gross alpha activity (µg/L as Uranium)	<0.4	<0.4	1.5	--	20	--
Gross alpha activity (pCi/L as Thorium-230)	<.4	<.4	1.6	15	20	0
Gross beta activity (pCi/L as Cesium-137)	.4	2.3	4.7	50	20	0
Gross beta activity (pCi/L as Strontium/ Yttrium-90)	<.4	1.8	3.8	50	20	0
Radium-226 (pCi/L)	<.02	.02	.04	--	20	--
Radium-228 (pCi/L)	<1.0	<1.0	1.4	[b]5	20	0
Radon-222 (pCi/L)	<80	315	820	--	76	--
Uranium (µg/L)	<1.0	<1.0	1.2	--	20	--

[a] Primary drinking water standard.

[b] Standard is for the sum of radium-226 and -228.

Organic Compounds

Few organic compounds were detected in the 20 samples analyzed for concentrations of volatile organic compounds, acid and base-neutral extractable compounds, pesticides, and polychlorinated biphenyls (fig. 9). All organic compounds analyzed by the NWQL (table 6) and all pesticide concentrations reported by the IRC (table 7) had median concentrations less than the detection limit. Although USEPA drinking water standards are available for only a few organic compounds, existing standards were met in all cases. Even so, the presence of any of these organic compounds in ground water is due to anthropogenic activities and indicates some degree of contamination. A summary of compounds detected and the wells from which the samples were collected is presented in table 8.

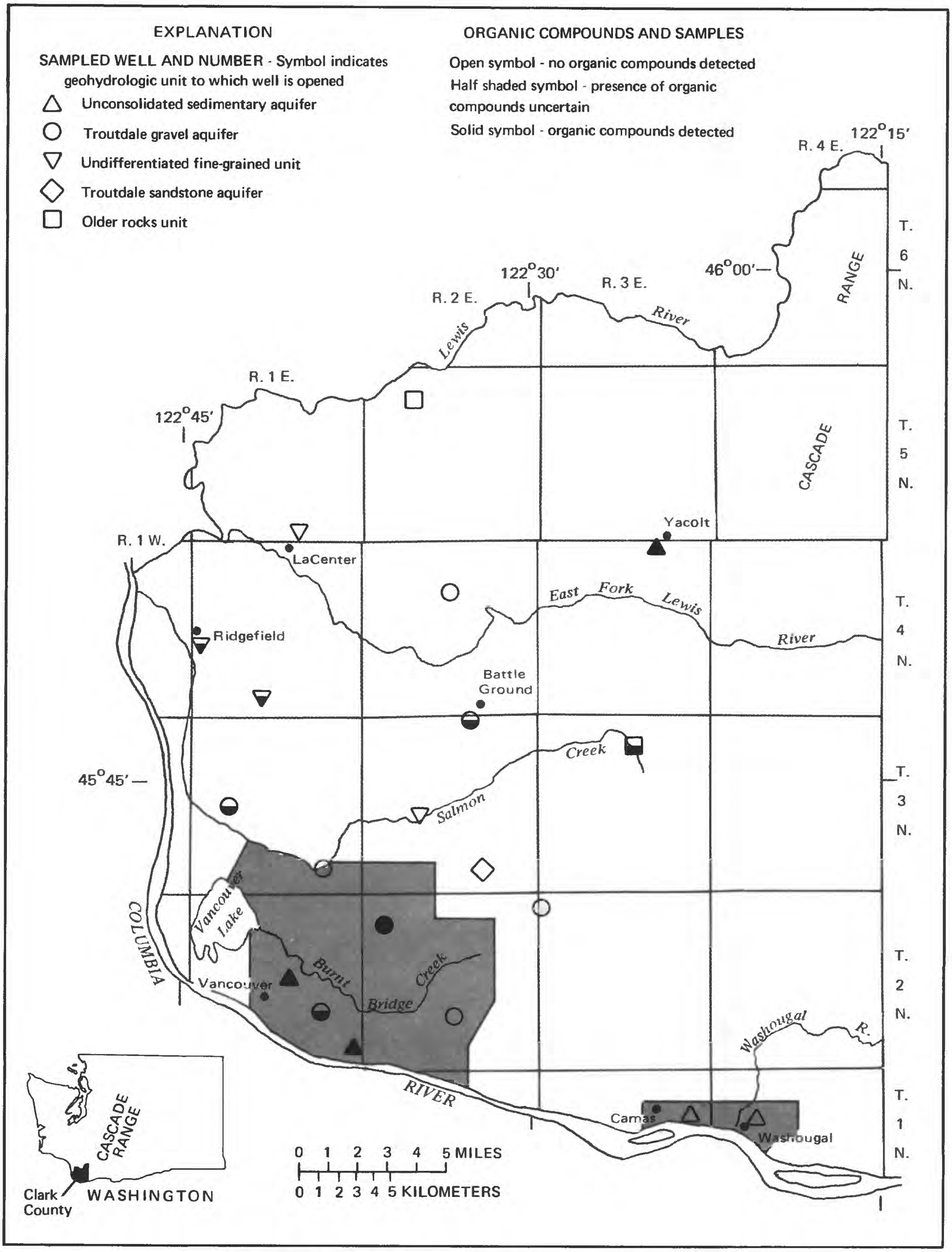

FIGURE 9.--Wells where samples were collected for organic analysis, and wells where organic compounds were detected.

Table 6.--Summary of concentrations of organic compounds

[Concentrations in micrograms per liter unless otherwise noted. All are total concentrations; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard; α, alpha; β, beta; δ, delta]

	Concentrations			USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
Constituent	Mini-mum	Median	Maxi-mum			
Volatile compounds						
Chloromethane	<0.2	<0.2	<0.2	--	20	--
Dichloromethane	<.2	<.2	<.2	--	20	--
Trichloromethane	<.2	<.2	4.8	--	20	--
Tetrachloromethane	<.2	<.2	<.2	5	20	0
Bromomethane	<.2	<.2	<.2	--	20	--
Dibromomethane	<.2	<.2	.2	--	20	--
Tribromomethane	<.2	<.2	<.2	--	20	--
Bromodichloromethane	<.2	<.2	<.2	--	20	--
Dibromochloromethane	<.2	<.2	<.2	--	20	--
Trichlorofluoromethane	<.2	<.2	1.3	--	20	--
Dichlorodifluoromethane	<.2	<.2	<.2	--	20	--
Chloroethane	<.2	<.2	<.2	--	20	--
1,1-Dichloroethane	<.2	<.2	<.2	--	20	--
1,2-Dichloroethane	<.2	<.2	<.2	5	20	0
1,1,1-Trichloroethane	<.2	<.2	6.8	200	20	0
1,1,2-Trichloroethane	<.2	<.2	<.2	--	20	--
1,1,1,2-Tetrachloroethane	<.2	<.2	<.2	--	20	--
1,1,2,2-Tetrachloroethane	<.2	<.2	<.2	--	20	--
1,2-Dibromoethane	<.025	<.025	<.025	--	20	--
Vinyl chloride	<.2	<.2	<.2	2	20	0
1,1-Dichloroethene	<.2	<.2	.9	7	20	0
cis 1,2-Dichloroethene	<.2	<.2	<.2	--	20	--
trans 1,2-Dichloroethene	<.2	<.2	<.2	--	20	--
Trichloroethene	<.2	<.2	.2	5	20	0
Tetrachloroethene	<.2	<.2	14	--	20	--
1,2-Dichloropropane	<.2	<.2	<.2	--	20	--
1,3-Dichloropropane	<.2	<.2	<.2	--	20	--
2,2-Dichloropropane	<.2	<.2	<.2	--	20	--
1,2,3-Trichloropropane	<.2	<.2	<.2	--	20	--
1,2-Dibromo-3-chloropropane	<.025	<.025	<.025	--	20	--
1,1-Dichloropropene	<.2	<.2	<.2	--	20	--
1,3-Dichloropropene	<.2	<.2	<.2	--	20	--
cis 1,3-Dichloropropene	<.2	<.2	<.2	--	20	--
trans 1,3-Dichloropropene	<.2	<.2	<.2	--	20	--
Benzene	<.2	<.2	.2	5	20	0
Chlorobenzene	<.2	<.2	<.2	--	20	--
1,2-Dichlorobenzene	<.2	<.2	<.2	--	20	--
1,3-Dichlorobenzene	<.2	<.2	<.2	--	20	--
1,4-Dichlorobenzene	<.2	<.2	<.2	75	20	0
Bromobenzene	<.2	<.2	<.2	--	20	--
Toluene	<.2	<.2	.5	--	20	--
2-Chlorotoluene	<.2	<.2	<.2	--	20	--
4-Chlorotoluene	<.2	<.2	<.2	--	20	--

Table 6.--Summary of concentrations of organic compounds--Continued

Constituent	Concentrations Minimum	 Median	 Maximum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
		Volatile compounds--Continued				
Dimethylbenzene	<.2	<.2	<.2	--	20	--
1,2-Dimethylbenzene	<.2	<.2	<.2	--	20	--
1,3-Dimethylbenzene	<.2	<.2	<.2	--	20	--
1,4-Dimethylbenzene	<.2	<.2	<.2	--	20	--
Ethylbenzene	<.2	<.2	<.2	--	20	--
Ethenylbenzene	<.2	<.2	<.2	--	20	--
2-Chloroethylvinyl ether	<.2	<.2	<.2	--	20	--
		Acid extractable compounds				
Phenol	<5	<5	<5	--	20	--
2,4-Dimethylphenol	<5	<5	<5	--	20	--
2-Chlorophenol	<5	<5	<5	--	20	--
2,4-Dichlorophenol	<5	<5	<5	--	20	--
2,4,6-Trichlorophenol	<20	<20	<20	--	20	--
Pentachlorophenol	<30	<30	<30	--	20	--
4-Chloro-3-methylphenol	<30	<30	<30	--	20	--
2-Nitrophenol	<5	<5	<5	--	20	--
4-Nitrophenol	<30	<30	<30	--	20	--
2,4-Dinitrophenol	<20	<20	<20	--	20	--
4,6-Dinitro-2-methylphenol	<30	<30	<30	--	20	--
		Base-neutral extractable compounds				
bis(2-chloroethoxy)methane	<5	<5	<5	--	20	--
Hexachloroethane	<5	<5	<5	--	20	--
Hexachlorobutadiene	<5	<5	<5	--	20	--
Hexachlorocyclopentadiene	<5	<5	<5	--	20	--
bis(2-chloroethyl) ether	<5	<5	<5	--	20	--
bis(2-chloroisopropyl) ether	<5	<5	<5	--	20	--
4-Chlorophenyl phenyl ether	<5	<5	<5	--	20	--
4-Bromophenyl phenyl ether	<5	<5	<5	--	20	--
1,2,4-Trichlorobenzene	<5	<5	<5	--	20	--
Hexachlorobenzene	<5	<5	<5	--	20	--
Nitrobenzene	<5	<5	<5	--	20	--
2,4-Dinitrotoluene	<5	<5	<5	--	20	--
2,6-Dinitrotoluene	<5	<5	<5	--	20	--
Isophorone	<5	<5	<5	--	20	--
Dimethyl phthalate	<5	<5	<5	--	20	--
Diethyl phthalate	<5	<5	<5	--	20	--
Di-n-butyl phthalate	<5	<5	<5	--	20	--

Table 6.--Summary of concentrations of organic compounds--Continued

Constituent	Concentrations			USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
	Minimum	Median	Maximum			
Base-neutral extractable compounds--Continued						
n-butyl benzyl phthalate	<5	<5	<5	--	20	--
Di-n-octyl phthalate	<10	<10	<10	--	20	--
bis(2-ethyl hexyl) phthalate	<5	<5	10	--	20	--
Naphthalene	<5	<5	<5	--	20	--
2-Chloronaphthalene	<5	<5	<5	--	20	--
Acenaphthylene	<5	<5	<5	--	20	--
Acenaphthene	<5	<5	<5	--	20	--
Fluorene	<5	<5	<5	--	20	--
Anthracene	<5	<5	<5	--	20	--
Benzo(a)anthracene	<5	<5	<5	--	20	--
Dibenzo(a,h)anthracene	<10	<10	<10	--	20	--
Phenanthrene	<5	<5	<5	--	20	--
Fluoranthene	<5	<5	<5	--	20	--
Benzo(b)fluoranthene	<10	<10	<10	--	20	--
Benzo(k)fluoranthene	<10	<10	<10	--	20	--
Pyrene	<5	<5	<5	--	20	--
Benzo(a)pyrene	<10	<10	<10	--	20	--
Indeno(1,2,3-cd)pyrene	<10	<10	<10	--	20	--
Chrysene	<10	<10	<10	--	20	--
Benzo(g,h,i)perylene	<10	<10	<10	--	20	--
n-nitrosodimethylamine	<5	<5	<5	--	20	--
n-nitrosodi-n-propylamine	<5	<5	<5	--	20	--
n-nitrosodiphenylamine	<5	<5	<5	--	20	--
Detergents						
Methylene blue active substance (milligrams per liter)	<.01	.01	.06	.5*	20	0
Pesticides						
Aldrin	.01	<.01	<.01	--	20	--
Chlordane	<.1	<.1	<.1	--	20	--
DDD	<.01	<.01	<.01	--	20	--
DDE	<.01	<.01	<.01	--	20	--
DDT	<.01	<.01	<.01	--	20	--
Dieldrin	<.01	<.01	<.01	--	20	--
Endosulfan	<.01	<.01	<.01	--	20	--
Endrin	<.01	<.01	<.01	.2	20	0
Heptachlor	<.01	<.01	<.01	--	20	--
Heptachlor epoxide	<.01	<.01	<.01	--	20	--

Table 6.--Summary of concentrations of organic compounds--Continued

Constituent	Concentrations Mini- mum	Concentrations Median	Concentrations Maxi- mum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
		Pesticides--Continued				
α-Hexachlorobenzene	<.01	<.01	<.01	--	20	--
β-Hexachlorobenzene	<.01	<.01	<.01	--	20	--
δ-Hexachlorobenzene	<.01	<.01	<.01	--	20	--
Lindane	<.01	<.01	<.01	4	20	0
Methoxychlor	<.01	<.01	<.01	100	20	0
Mirex	<.01	<.01	<.01	--	20	--
Perthane	<.1	<.1	<.1	--	20	--
Toxaphene	<1	<1	<1	5	20	0
		Polychlorinated biphenyls				
Aroclor 1016	<0.1	<0.1	<0.1	--	20	--
Aroclor 1221	<.1	<.1	<.1	--	20	--
Aroclor 1232	<.1	<.1	<.1	--	20	--
Aroclor 1242	<.1	<.1	<.1	--	20	--
Aroclor 1248	<.1	<.1	<.1	--	20	--
Aroclor 1254	<.1	<.1	<.1	--	20	--
Aroclor 1260	<.1	<.1	<.1	--	20	--

[a] Primary drinking water standard unless noted with an asterisk, in which case the number is a secondary drinking water standard.

Table 7.--Summary of pesticide concentrations reported by the Intergovernmental Resource Center

[Concentrations in micrograms per liter. All are total concentrations; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Pesticide	Concentrations Mini- mum	Concentrations Median	Concentrations Maxi- mum	USEPA[a] drinking water standard	Number of wells sampled	Number of wells exceeding standard
Atrazine	<5	<5	10	--	20	--
Simazine	<5	<5	<5	--	20	--
2,4-D	<.5	<.5	7.3	100	20	0
2,4,5-TP silvex	<.15	<.15	<.15	10	20	0
Dinoseb	<.4	<.4	<.4	--	20	--
Dalapon	<.5	<.5	<.5	--	20	--
Glyphosate	<3	<3	<3	--	20	--

[a] Primary drinking water standards.

Table 8.--Concentrations of organic compounds in samples where organic compounds were present

[Concentrations in micrograms per liter unless otherwise noted; mg/L, milligrams per liter; --, compound not analyzed for]

Local well number	Date	Di-chlor-meth-ane total	Tri-chloro-meth-ane total	Di-bro-mo-meth-ane total	Tri-chloro-fluoro-methane total	1,1,1-Tri-chloro-ethane total	1,1-Di-chloro-ethene total	Tri-chloro-ethene total	Tetra-chloro-ethene total	Benzene total	Toluene total	bis(2-ethyl hexyl) phthal-ate total	Methy-lene blue active sub-stance (mg/L)	2,4-D[a] total	Atra-zine[a] total
02N/01E-15Q01	05-03-88	<0.2	4.8	<0.2	<0.2	6.8	0.9	<0.2	<0.2	<0.2	<0.2	10	0.06	<0.5	<5
02N/01E-23Q03	04-28-88	<.2	<.2	<.2	<.2	.3	<.2	<.2	.3	<.2	<.2	<5	.03	<.5	<5
02N/01E-36B09	04-28-88	--	--	--	--	--	--	--	--	--	--	<5	.04	<.5	<5
	07-20-88	<.2	.2	<.2	1.3	.7	<.2	<.2	14	<.2	<.2	--	--	--	--
02N/02E-07A02	04-27-88	<.2	<.2	<.2	<.2	.4	<.2	.2	1.4	<.2	<.2	<5	.02	<.5	10
	04-27-88	<.2	<.2	<.2	<.2	.2	<.2	.2	.7	<.2	<.2	<5	.04	<.5	<5
	08-02-88	--	--	--	--	--	--	--	--	--	--	--	--	--	<3
03N/01E-17P01	04-30-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<5	.01	<.5	<5
	04-30-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	1.3	<.2	<.2	<5	.01	<.5	<5
03N/02E-03B01	04-25-88	--	--	--	--	--	--	--	--	--	--	<5	.01	<.5	<5
	07-19-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.6	<.2	<.2	--	--	--	--
03N/02E-20H01	04-28-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	8	.01	<.5	<5
03N/03E-03P01	04-26-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<5	.01	.7	<5
	07-19-88	--	--	--	--	--	--	--	--	--	--	--	--	<.5	--
04N/01E-19F02	04-29-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.2	.5	<5	.01	<.5	<5
04N/01E-33B02	04-30-88	<.2	<.2	.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<5	.01	<.5	<5
04N/03E-02D02	04-25-08	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<5	.01	7.3	<5
	07-19-88	--	--	--	--	--	--	--	--	--	--	--	--	<.5	--
Deionized water	04-26-88	--	--	--	--	--	--	--	--	--	--	<5	.01	<.5	<5
blank	04-29-88	<.2	<.2	<.2	<.2	<.2	<.2	<.2	.3	<.2	.4	15	.01	<.5	<5
	05-03-88	1.1	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	--	--	--	-

[a] Data provided by the Intergovernmental Resource Center.

Most of the organic compounds present were volatiles (table 8). Concentrations of 1,1,1-trichloroethane and tetrachloroethene were largest, as large as 6.8 and 14 µg/L, respectively. Samples from wells 02N/01E-15Q01, 02N/01E-36B09, and 02N/02E-07A02 each had concentrations greater than 1.0 µg/L for at least one of these two compounds, along with smaller concentrations of one or more of the following compounds; trichloromethane, trichlorofluoromethane, 1,1-dichloroethene, or trichloroethene. The samples from these three wells indicate the presence of volatile organic compounds in the ground water.

Samples from other wells are not as conclusive (table 8). Samples from well 02N/01E-23Q03 were reported to contain both tetrachloroethene and 1,1,1-trichloroethane, each at concentrations of 0.3 µg/L. The actual presence of these compounds in the ground water is doubtful, because this concentration is near the detection limit of 0.2 µg/L for both compounds and tetrachloroethene was detected at 0.3 µg/L in a blank sample. The presence of 0.6 µg/L of tetrachloroethene in the sample from well 03N/02E-03B01 is also small enough to be questionable because of the positive blank. Similarly, concentrations of benzene at 0.2 µg/L and toluene at 0.5 µg/L in the sample from well 04N/01E-19F02 are inconclusive because of the small concentrations and the presence of 0.4 µg/L toluene in a blank. The sample from well 04N/01E-33B02 was reported to contain 0.2 µg/L dibromomethane, which is questionable because it is at the detection limit. Also in question is the concentration of tetrachloroethene in the ground water at well 03N/01E-17P01, where one sample had a concentration of <0.2 µg/L, but a duplicate sample had a concentration of 1.3 µg/L. In general, concentrations reported for volatiles in samples from the five wells discussed here are inconclusive and must be considered in relation to concentrations reported in blanks and the presence of other compounds.

Other organic compounds detected included bis(2-ethylhexyl)phthalate in samples from wells 02N/01E-15Q01 and 03W/02E-20H01 (table 8). This compound was the only acid or base-neutral extractable compound reported above the detection limit. However, the concentration in one blank exceeded concentrations reported for the samples. Considering the concentration in the blank and the common occurrence of phthalates in plastics, these concentrations are probably not representative of the ground water, especially at the second well where the sample was collected through plastic pipe. Methylene blue active substances (MBAS), or detergents, were present in most samples at concentrations of 0.01 mg/L. The largest concentrations of 0.04 to 0.06 mg/L are still small compared to the USEPA standard of 0.5 mg/L, but were found in the three wells containing the largest concentrations of volatiles, implying a common source for the volatile organic compounds and MBAS.

The only other organic compounds detected were pesticides reported by the IRC. Atrazine was detected at 10 µg/L in one sample from well 02N/02E-07A02, and 2,4-D was detected at 7.3 µg/L in the sample from well 04N/03E-02D02. These levels are large enough to suggest ground-water contamination. The sample from well 03N/03E-03P01 also was reported to contain 2,4-D, but at a concentration of 0.7 µg/L, which is small enough to be questionable because the detection limit was 0.5 µg/L. The last two wells are in somewhat rural locations where pesticide use is likely to be greater. All three wells were resampled, and no pesticides were detected.

Samples from some municipal wells were analyzed in March 1988 for concentrations of volatile organic compounds by the Washington State Department of Social and Health Services (DSHS). These samples were either composites collected from as many as five different wells, or were collected from a compositing distribution system from a well field. Also, the samples were collected after treatment, which included chlorination. The results (table 9), therefore, are not directly comparable with data from this study, but some observations can be made. Tetrachloroethene was found in samples including wells 02N/01E-23Q03 and 02N/01E-36B09, and 1,1,1-trichloroethane was found in samples including well 02N/01E-15Q01, agreeing with the data collected by the Geological Survey. Trichloromethane, tribromomethane, dibromochloromethane, and bromodichloromethane were detected in virtually all the samples collected by DSHS, but were not detected in the Geological Survey samples except for trichloromethane in samples from wells 02N/01E-15Q01 and 02N/01E-36B09. However, all four compounds are trihalomethanes (THMs), which are known to be produced in natural waters that are chlorinated (Rook, 1974). Concentrations of all other organic compounds in the DSHS samples were less than the detection limit of 0.5 μg/L, but apparent discrepancies that these data create with the Geological Survey data could be explained by the larger detection limit or compositing of the DSHS samples.

Table 9.--Concentrations of volatile organic compounds present in composite samples from municipal wells. Samples analyzed by State of Washington Department of Social and Health Services (DSHS), March 1988

[Concentrations in micrograms per liter]

Representative well in composite sample[a]	Trichloromethane	Tribromomethane	Dibromochloromethane	Bromodichloromethane	1,1,1-Trichloroethane	Tetrachloroethene
02N/01E-15Q01	4.4	1.8	3.2	1.8	2.9	<0.5
02N/01E-23Q03	1.0	.7	1.8	1.4	<.5	1.5
02N/01E-36B09	<.5	1.2	2.5	1.5	<.5	8.2
02N/02E-07A02	<.5	3.8	4.8	1.8	<.5	<.5
02N/02E-27D02	<.5	<.5	.9	.6	<.5	<.5
03N/01E-35D02	.9	<.5	2.0	1.6	<.5	<.5

[a] The sample analyzed was either a composite collected from as many as five different wells or was collected from a distribution system that combines flow from several wells in a well field. The well shown is the well sampled by the U.S. Geological Survey that is also part of the composite sample analyzed by DSHS.

Spatial Distribution of Water-Quality Constituents

The spatial distribution of water-quality constituents with depth, geohydrologic unit, flow path, and general land use were examined and for the common constituents and a few organic compounds, were related to possible causes. For bacteria, trace elements, radiochemical constituents, and most organic compounds, either there were no meaningful patterns, or no obvious causes could be found. The relations discussed are regional in nature, and therefore local geohydrologic conditions may result in water chemistries that differ from regional patterns.

Dissolved Solids and Common Ions

One of the most significant patterns in the ground-water chemistry is the increase of dissolved-solids concentrations along regional flow lines. In figure 10, it is evident that dissolved-solids concentrations increased from the northeast to the southwest, along the regional ground-water flow paths (see fig. 5). This trend is consistent with the concept that mineralization of ground water usually increases with the increased residence time as water moves downgradient. Many samples from upgradient wells had dissolved-solids concentrations less than 100 mg/L. The sample from well 02N/04E-36N01, which is in an area of relatively high recharge, had a dissolved-solids concentration of 12 mg/L. This concentration approaches that of rainwater, suggesting a short residence time. Most samples from downgradient wells, especially those in townships 02N/01E, 03N/01E, and 04N/01E, had dissolved-solids concentrations larger than 175 mg/L.

The median dissolved-solids concentrations in the older rocks unit was 112 mg/L, smaller than in the other four units, where median concentrations range from 138 to 161 mg/L (table 10). The reason for lower dissolved-solids concentrations in the older rocks unit probably is that most of the wells open to this unit are in upgradient areas of the county. Aquifers in basalt, of which much of the older rocks unit is composed, are capable of producing water with dissolved-solids concentrations exceeding 200 mg/L (Turney, 1986b, 1986c). For example, a sample from well 04N/01E-18J01, a well that is open to the older rocks unit and is downgradient in the flow system, had a dissolved-solids concentration of 228 mg/L. However, samples from several upgradient wells in the older rocks unit, including those from wells 04N/03E-28R02, 05N/03E-16P01, and 05N/03E-27N02, had dissolved-solids concentrations less than 100 mg/L. It is, therefore, unlikely that the spatial distribution of dissolved solids is due solely to different geohydrologic units. More likely causes are variations in residence time, flow-path length, chemical composition of the geohydrologic unit, and land use.

Calcium-bicarbonate and calcium-magnesium-bicarbonate were the predominant water types in the upper four geohydrologic units, but many samples in the older rocks unit had larger proportions of sodium, enough so that many sodium-calcium-bicarbonate or sodium-bicarbonate water types are found. This is illustrated by plotting the percentages (based on milliequivalents) of the major ions for a sample on a trilinear diagram (fig. 11). The diagram can then be used to identify the water type on the basis of the predominant cation(s) and anion(s). Separate diagrams are shown for each geohydrologic unit. The diagram for the older rocks unit shows more scatter towards a larger percentage sodium than do the diagrams for the other units. Statistically, the median proportion of sodium was 38 percent in samples from the older rocks unit, approximately twice that of other units (table 10). Also, the median concentration of sodium was almost twice as large in ground-water samples from the older rocks unit than in samples from other units. Median calcium concentrations were somewhat smaller in the older rocks unit, but much of this may be due to the generally smaller dissolved-solids concentrations. Magnesium and potassium concentrations were substantially smaller in the older rocks unit.

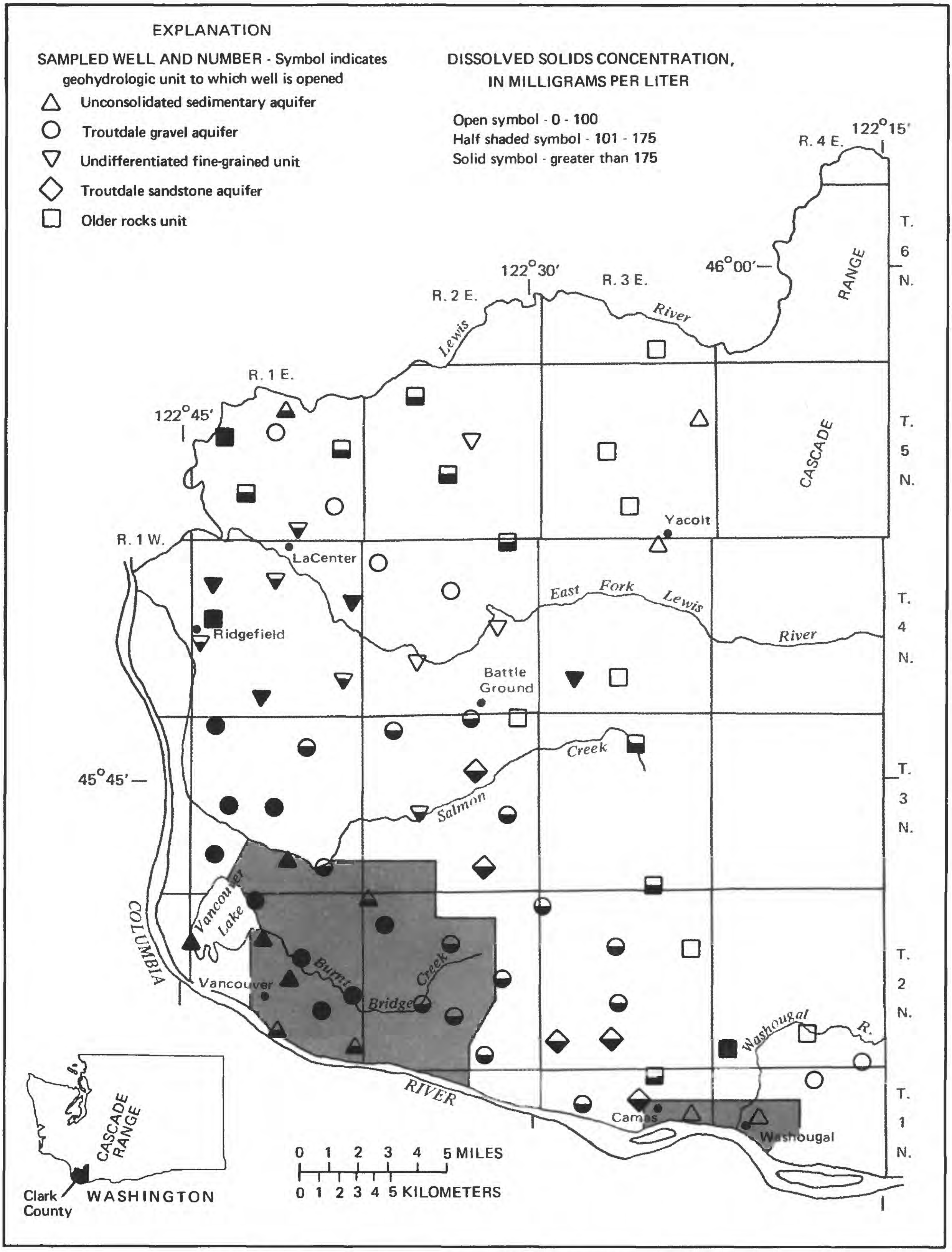

FIGURE 10.--Areal distribution of dissolved-solids concentrations.

Table 10.--Median values and concentrations of common constituents by geohydrologic unit

[Concentrations in milligrams per liter (mg/L) unless otherwise noted. All are dissolved concentrations; μS/cm, microsiemens per centimeter at 25 °Celsius; NTU, nephelometric turbidity units; μg/L, micrograms per liter]

	Geohydrologic unit				
Constituent	Unconsolidated sedimentary aquifer	Troutdale gravel aquifer	Undifferentiated fine-grained or confining unit 1	Troutdale sandstone aquifer	Older rocks
	Number of samples				
	12	29	12	5	18
Specific conductance (μS/cm)	226	187	186	168	137
pH (standard units)	6.8	6.9	7.0	7.3	7.9
Dissolved oxygen	5.6	5.8	1.7	1.5	4.4
Turbidity (NTU)	.3	.3	.7	.2	.3
Hardness as $CaCO_3$	95	78	75	75	43
Calcium	23	19	19	16	14
Magnesium	8.7	8.1	7.4	8.5	1.7
Sodium	6.3	6.7	9.3	7.8	14
Percent sodium	14	17	22	18	38
Potassium	2.6	2.0	1.1	1.9	.3
Bicarbonate	103	96	110	113	80
Carbonate	0	0	0	0	0
Alkalinity as $CaCO_3$ (Field)	85	79	90	93	69
Sulfate	8.1	1.8	1.5	1.0	1.3
Chloride	5.3	3.0	2.3	1.6	2.3
Fluoride	.2	.2	.3	.2	.2
Silica	45	51	48	45	31
Dissolved solids	161	[a]144	138	139	112
Nitrate	1.9	.58	.11	<.10	<.10
Phosphorus	.08	.07	.07	.09	.03
Aluminum (μg/L)	<10	<10	<10	<10	<10
Iron (μg/L)	<3	5	38	3	4
Manganese (μg/L)	<1	2	4	2	2

[a] Based on only 28 samples.

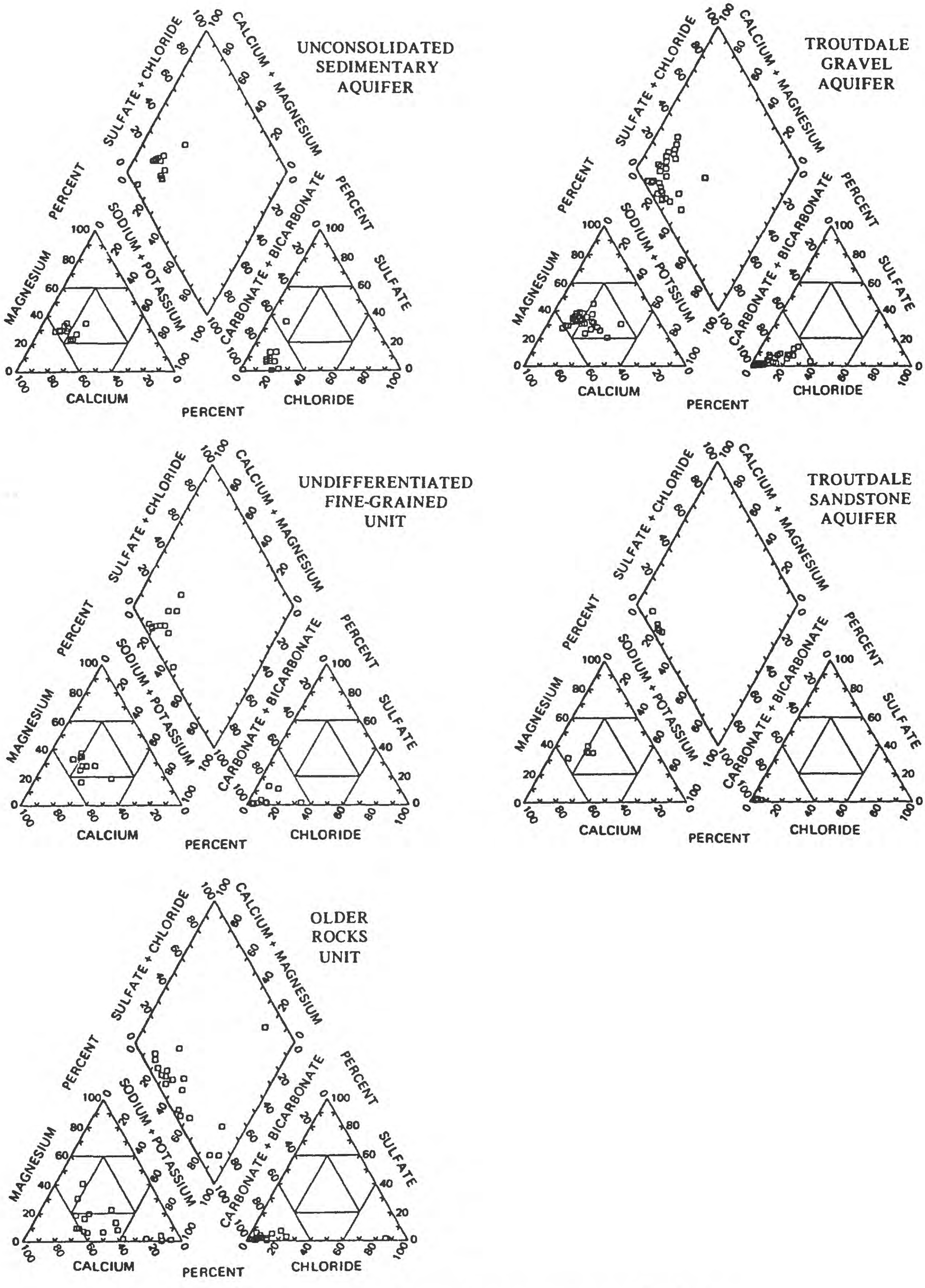

FIGURE 11.--Trilinear diagrams showing percentages of major ions in water samples, by geohydrologic unit.

The elevated sodium concentrations in the older rocks unit are likely due to geochemical reactions of ground water with the basalt contained in the unit. The reactions of ground water in basalt have been investigated in eastern Washington by Hearn and others (1985) and by Steinkampf and others (1985), and similar reactions probably occur in the older rocks unit of Clark County. Initially, slightly acidic calcium-bicarbonate water from precipitation or the upper units enters the older rocks unit as a result of the predominantly downward vertical flow. This water begins to dissolve the basaltic minerals which contain sodium. Hydrolysis is part of the dissolution mechanism and produces excessive hydroxol ions that raise the ground-water pH. Solubilities for silica, calcium carbonate, and magnesium carbonate, which are pH-controlled, are exceeded, and these minerals precipitate. However, the solubility of the sodium minerals is not exceeded, resulting in water with a large concentration of sodium and small concentrations of calcium and magnesium. The pH is also larger, as can be seen by the larger median pH in the older rocks unit (table 10). The increased pH also causes some of the bicarbonate to convert to carbonate.

Unlike the cations, anion proportions were similar in all units (fig. 11). Bicarbonate concentrations were slightly smaller in the older rocks unit than in the four overlying units. Median concentrations of chloride and fluoride (table 10) were much smaller than bicarbonate concentrations and vary little between units. Median concentrations of sulfate were also small, but the median sulfate concentration in the unconsolidated sedimentary aquifer was 8.1 mg/L, more than four times as large as in the other units. In only one sample, from well 02N/04E-31G01, bicarbonate was not the predominant anion. In this sample, chloride was the predominant anion, and sodium chloride was the predominant water type. This sample also had a dissolved-solids concentration of 245 mg/L, the largest of all samples analyzed. The reason for the anomalous chemistry in the water from this well is unknown.

Nitrate and Sulfate

Nitrate concentrations, although not a major component of any of the water analyzed, are of concern in some areas of Clark County because of the implications of contamination associated with nitrate and because the largest concentrations found in this study (6.7 mg/L as N) approached the USEPA drinking water standard of 10 mg/L as N. The samples with the largest nitrate concentrations were collected from wells in the Vancouver urban area in the southwestern part of the county (fig. 12). Concentrations exceeded 1.0 mg/L in almost all samples from this area. Few samples from the rest of the county had nitrate concentrations greater than 1.0 mg/L. Median concentrations of nitrate in samples from the unconsolidated sedimentary aquifer and Troutdale gravel aquifer are 1.9 mg/L and 0.58 mg/L, respectively, substantially larger than in samples from the other units (table 10). This can be expected, because these two units are nearest the surface in the most populated area of the county. The source of nitrate in ground water in urban environments is usually septic systems, but lawn and garden fertilizers could also be major sources (Porter, 1980). Large nitrate concentrations outside of the Vancouver urban area also could be due to agricultural fertilizers.

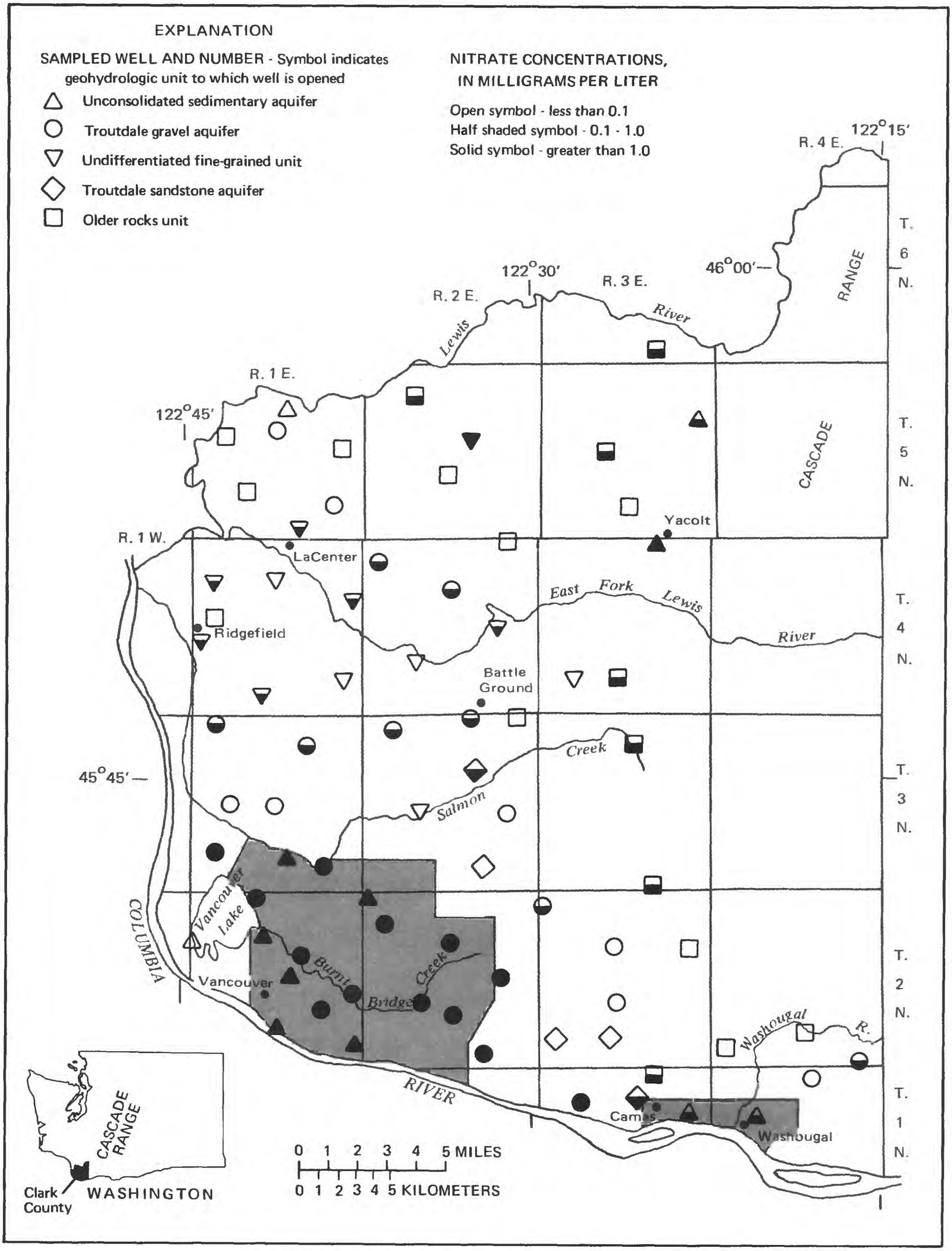

FIGURE 12.--Areal distribution of nitrate concentrations.

The correlation coefficient of nitrate concentrations to sulfate concentrations was 0.61. A graphical comparison of sulfate and nitrate shows some relation (fig. 13). If the two outliers in figure 13 are omitted, the correlation coefficient increases to 0.74. (The correlation coefficients were calculated two ways, with nondetect values set to the detection limit, and with nondetect values set to zero; there was no significant difference in the resulting values.) Sulfur-containing minerals are not common in Clark County, so natural materials are not a likely source of sulfate. However, sulfate is present in septic wastes and some fertilizers; therefore, these could be sources of sulfate as well as nitrate in the ground water. The average ratio of nitrogen to sulfur in the ground-water samples is about 2:1 on a molar concentration basis, but this could vary by an order of magnitude for individual samples. Ammonia sulfate, a common lawn fertilizer, has a molar concentration ratio of nitrogen to sulfur of 2:1, and ratios in septic tank effluent are probably similar to those of sewage treatment effluent, which are approximately 7:1. However, the nitrogen-to-sulfur ratio found in potential sources could be reduced in the ground water by the uptake of nitrogen by plants. Considering the correlation between sulfate and nitrate, the concentration ratios in the ground water and in potential sources, and the lack of natural sources, it appears that sulfate in the ground water could come from the same sources as nitrate.

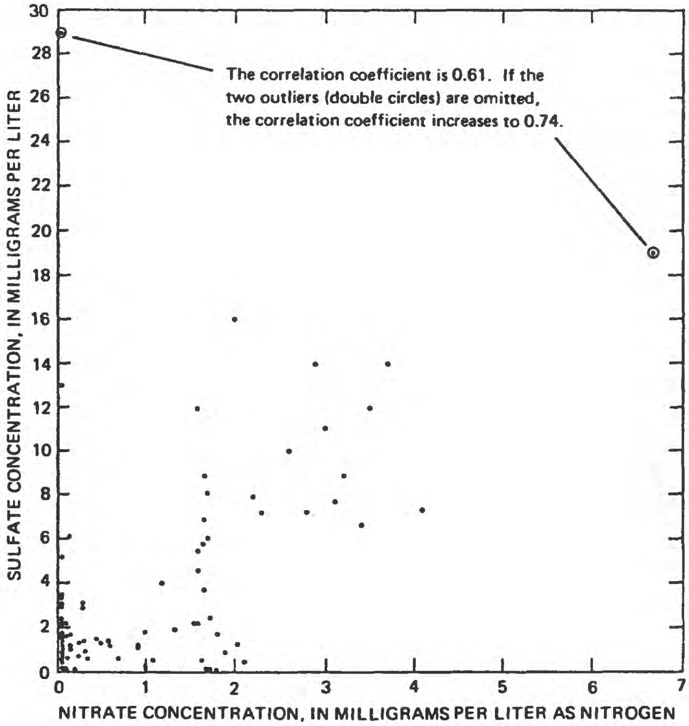

FIGURE 13.--Nitrate and sulfate concentrations.

Iron

The median iron concentration in the undifferentiated fine-grained unit was 38 μg/L, much larger than in any other unit (table 10). Even so, concentrations greater than 100 μg/L were found in samples from the unconsolidated sedimentary aquifer and Troutdale gravel aquifer. All wells with water containing 30 μg/L or more of dissolved iron are shown in figure 14, and the percentage of these wells is greater in the northwest part of the county than in other areas. Many water systems in the northwest part of the county are treated for large concentrations of dissolved or particulate iron.

The processes controlling concentrations of iron in ground-water systems can be closely dependent on local conditions. These processes begin with the depletion of dissolved oxygen in the ground water through organic oxygen-demand reactions or mineral-dissolution reactions. The oxygen-depleted water then dissolves iron from the surrounding minerals, if present, in a chemically reduced ferrous form (Fe^{2+}). The solubility of iron is large under these conditions. If the water is reoxygenated, either through chemical reactions, biological reactions, or mechanical aeration, then the iron is oxidized to Fe^{3+}, which is much less soluble than Fe^{2+} and will precipitate as an oxide (Fe_2O_3) or hydroxide ($Fe(OH)_3$). Because these reactions are oxygen-sensitive and the oxygen content of the ground water may vary considerably in a given area, dissolved-iron concentrations can vary greatly.

Organic Compounds

Only a few organic compounds had any obvious areal trends. Samples containing substantial concentrations of volatile organic compounds came from wells located in the Vancouver urban area. The volatile compounds identified are commonly used as solvents or degreasers by businesses such as dry cleaners, service stations, or machine shops. Samples containing pesticides were from wells in rural or suburban locations, where greater pesticide use would be expected.

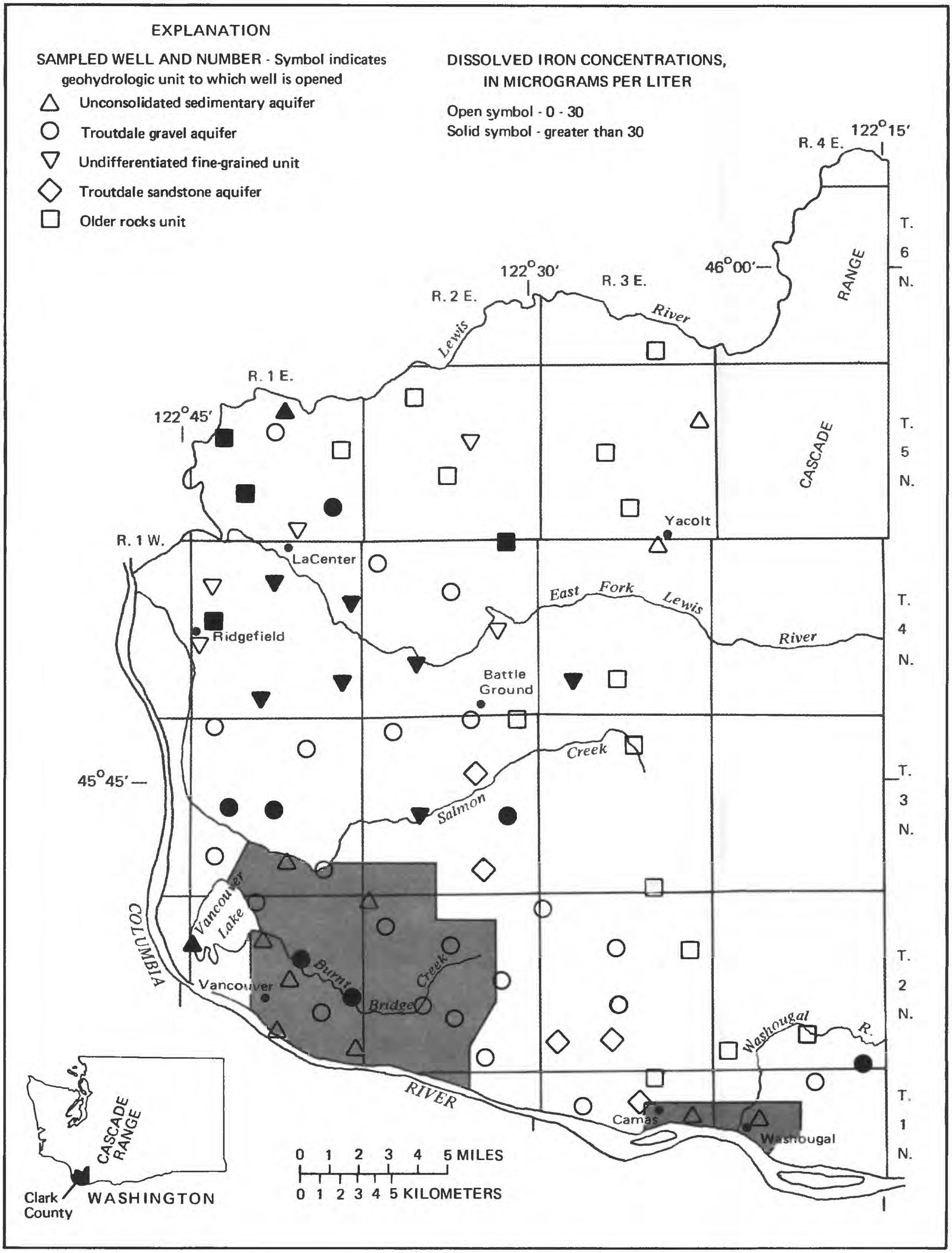

FIGURE 14.--Areal distribution of dissolved-iron concentrations.

Historical Changes in Nitrate Concentration

There is concern that nitrate concentrations could be increasing with time, especially in the Vancouver urban area. Nitrate concentrations from this study were compared with historical nitrate concentrations available for 16 of the sampled wells (fig. 15). These data are shown in table 11, and were obtained from the U.S. Geological Survey, WDOE, and DSHS files. Of the 16 wells, 9 samples from the present (1988) study had larger nitrate concentrations than from historical data, 6 had smaller concentrations, and 1 had the same concentration (fig. 15). At all six wells where nitrate concentrations decreased, concentrations in the present (1988) samples are larger than 1.0 mg/L; five of these wells are located in the Vancouver urban area. Conversely, at the 10 wells where nitrate concentrations in ground water either increased or remained constant, only 3 samples had a present (1988) concentration larger than 1.0 mg/L. Most of the wells where increases were noted are located in rural areas or smaller towns. Apparently, nitrate concentrations in ground water may be decreasing, or at least remaining constant, in urban areas where concentrations are already relatively large, but may be increasing in rural areas where concentrations are smaller. Any seasonal or temporal variations for Clark County are not known, but may contribute significantly to the observed differences.

Table 11.--Comparison of nitrate concentrations from the present (1988) study with historical nitrate concentrations

[Values in milligrams per liter (mg/L)]

Well location number	Nitrate concentration, 1988 (mg/L as N)	Historical nitrate concentration (mg/L as N; year in parenthesis)	Difference between 1988 and median historic concentrations
01N/03E-12L04	0.31	0.22(1980)	0.09
02N/01E-15Q01	3.50	3.3(1981), 5.2(1979)	-.8
02N/01E-23Q03	3.00	3.6(1979), 2.7(1955)	-.2
02N/01E-36B09	2.90	4.3(1979)	-1.4
02N/02E-10N03	4.10	4.0(1981), 4.3(1980), 5.2(1979)	-.2
02N/02E-14R04	3.40	3.4(1980), 3.2(1979)	.1
02N/02E-35M02	2.30	2.4(1980)	-.1
03N/01E-27P01	3.20	2.4(1985)	.8
03N/01E-35B02	1.20	1.0(1985), 0.7(1979), 0.6(1977), 0.8(1976)	.4
03N/02E-03B01	1.00	0.9(1985), 0.9(1979)	.1
03N/02E-35D02	<.10	<0.1(1985)	0
03N/03E-03P01	.34	<0.1(1985)	>.24
04N/03E-02D02	1.80	2.0(1987), 2.0(1984)	-.2
04N/03E-28R02	.25	<0.1(1985)	>.15
05N/01E-34G04	.48	0.3(1976)	.18
05N/03E-12P01	.68	0.07(1958)	.61

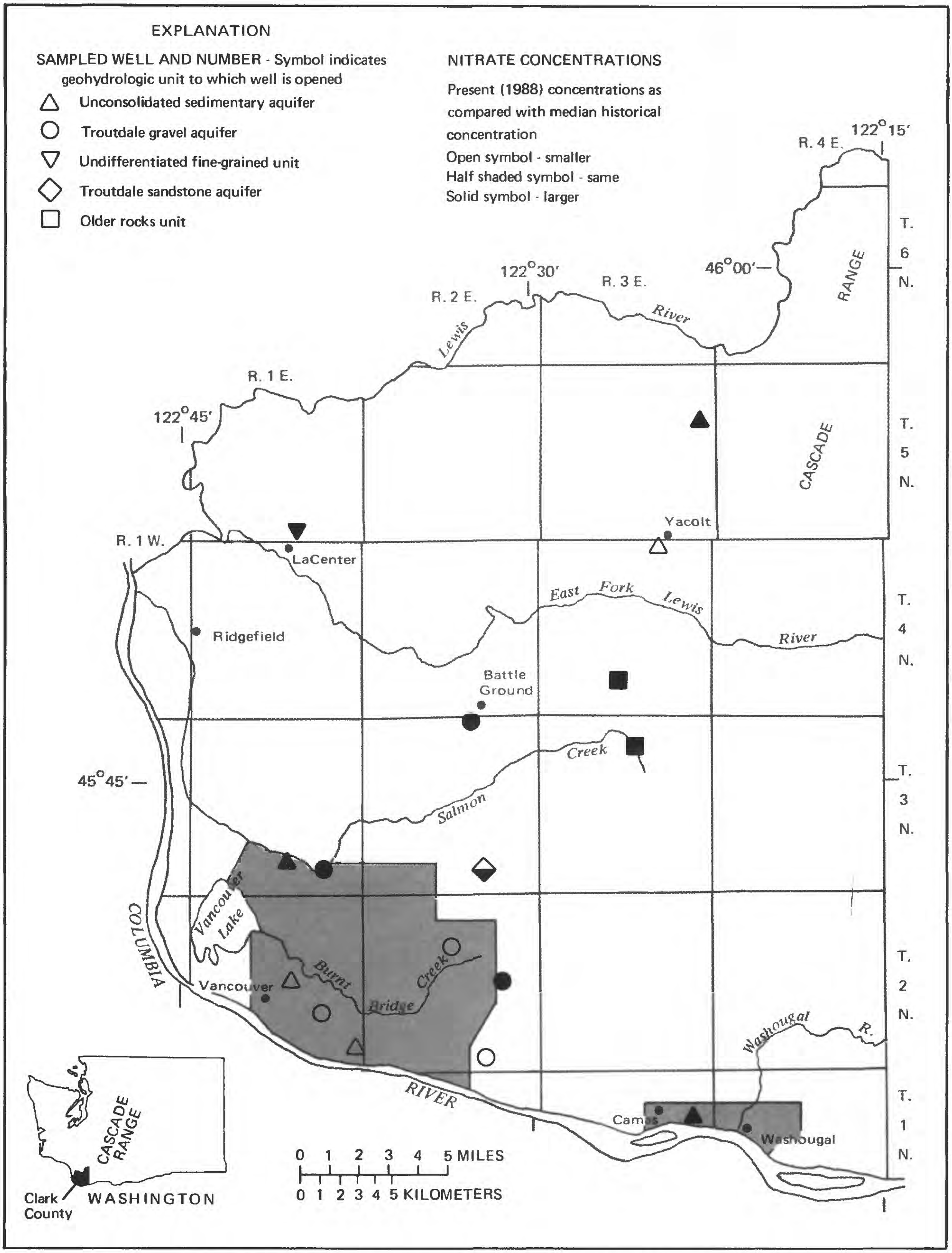

FIGURE 15.--Location of wells having both present (1988) and historical nitrate-concentration data, and differences between present and historical nitrate concentrations.

SUGGESTIONS FOR FUTURE MONITORING

This study has broadly characterized the ground-water quality of Clark County, but some problems (or potential problems) were identified that can be defined only with future monitoring. A monitoring program would address the following issues, presented in general order of importance.

Nitrate--Both large concentrations in the Vancouver urban area and smaller concentrations in rural areas need to be monitored seasonally over several years for change.

Organic Compounds--The occurrence of moderate concentrations of volatile organic compounds in samples from three wells in the Vancouver area needs to be investigated and monitored. A study identifying potential sources and remedial action also could be conducted, but is outside the scope of a general monitoring program. The presence of volatile organic compounds or pesticides in several other wells also needs to be verified by follow-up sampling.

Bacteria--The occurrence of bacteria in ground water was common but sporadic, and needs to be monitored seasonally for at least 1 year.

Routine Monitoring--A number of selected wells would be monitored every 3 years for all of the constituents analyzed for this study (common constituents, trace elements, organic compounds, and radiochemical constituents) to detect any future occurrences or changes. Selected wells also would be monitored seasonally for changes in concentrations of common constituents.

Sulfate--At this point, the relation between the occurrence of sulfate and nitrate is somewhat tenuous, but it may be of interest to monitor sulfate concentrations along with nitrate concentrations. Little work has been done on this relation, but if substantiated, it would be of interest in future environmental studies.

Iron, Manganese, pH, and Turbidity--Because these constituents are controlled by natural geochemical reactions and pose no health risk, there is little need to monitor them.

SUMMARY

This study was conducted to define representative concentrations of inorganic and organic constituents in ground water throughout Clark County, Washington. In April and May 1988, samples were collected from 76 wells in the county and were analyzed for concentrations of common constituents, including major ions, nitrate, iron, manganese, radon, and bacteria. Additional samples were collected from 20 of the wells for the analysis of an extensive suite of trace elements and organic compounds, including volatile organic compounds, acid and base-neutral extractable compounds, selected pesticides and polychlorinated biphenyls. Concentrations of constituents were compared with applicable USEPA drinking water standards, and the spatial distribution of concentrations with depth, geohydrologic unit, flow path, and land use was examined. The samples were collected from wells open to one of the geohydrologic units defined in the first phase of this study. From the surface down, these units are the unconsolidated sedimentary aquifer, Troutdale gravel aquifer, confining unit 1, Troutdale sandstone aquifer, confining unit 2, sand and gravel aquifer, and older rocks unit. Where the Troutdale sandstone aquifer does not occur, the confining units are indistinguishable and form the undifferentiated fine-grained unit.

Ground water in the county has a low dissolved-solids concentration, ranging from 12 to 245 mg/L with a median concentration of 132 mg/L. The major dissolved constituents are calcium, bicarbonate, and silica, but in some samples concentrations of magnesium, sodium, carbonate, sulfate, and chloride are also large. Most of the waters are soft to moderately hard. The only constituents present at levels not meeting USEPA drinking water standards were pH, turbidity, iron, manganese, and total coliform bacteria, and all occurrences except the total coliform likely are due to natural geohydrologic conditions.

Total coliform or fecal streptococci bacteria were present in samples from 26 wells. When these 26 wells and 2 control wells were resampled, the positive results were confirmed for only 3 wells. The sources are uncertain, but the bacteria are not likely due to regional conditions. Possible sources are natural bacteria in the soil or contamination from the well plumbing. Poor well construction also may be a factor. No fecal coliform bacteria were detected in any of the samples.

Concentrations of trace elements and radiochemical constituents were present at small levels, or were below detection limits. Although plumbing systems might have been the source of some elevated zinc and copper concentrations, the occurrences of most of the other constituents were probably due to natural conditions.

Substantial concentrations of volatile organic compounds were present in samples from three wells, all in the Vancouver area. Volatile organic compounds identified included 1,1,1-trichloroethane, tetrachloroethene, and other solvents that typically are used by drycleaners, service stations, and machine shops. Several samples from other wells contained trace amounts of volatile organic compounds, but it is questionable whether the small concentrations represent ground-water conditions. Atrazine was also detected

in one well, and 2,4-D was detected in samples from two wells. Upon resampling, neither pesticide was detected. No other organic compounds analyzed for were determined to be present in ground water, including the acid and base-neutral extractables, organochlorine pesticides, and polychlorinated biphenyls.

Patterns of spatial distributions were most apparent for concentrations of dissolved solids and common ions. Concentrations of dissolved solids generally increase downgradient along ground-water flow paths, which are from the Cascade Range foothills in the north and east to the Columbia River on the western and southern borders. This increase is due to the mineralization of the downgradient water because of longer residence times. Water from the lowest geohydrologic unit, the older rocks unit, contained sodium in proportions larger than in the other units, probably as a result of geochemical reactions with the basalt that makes up much of the older rocks unit.

There was also a pattern to the spatial distribution of nitrate concentrations. Although the median concentration for the county was 0.16 mg/L as nitrogen, concentrations within the Vancouver urban area exceeded 1.0 mg/L in all samples except one and were as large as 6.7 mg/L. Nitrate concentrations correlated with sulfate concentrations, and the two constituents could have similar sources, including septic systems and lawn or garden fertilizers. A comparison with historical data indicates that nitrate concentrations actually might have decreased within the urban area, but might be increasing in some rural areas.

Most samples with iron concentrations exceeding 30 μg/L came from the northwestern part of the county. Many water systems in the area require treatment for dissolved iron or suspended particulate iron oxide. Whether the iron is dissolved or suspended depends largely on the dissolved-oxygen content of the water.

A monitoring program might be necessary to further define some ground-water-quality problems. The program would address spatial distributions and changes in nitrate concentrations, the presence of volatile organic compounds, the presence of bacteria, and the possible relation between nitrate and sulfate. Monitoring selected wells for all constituents examined in this study would also help detect any changes in concentration of those constituents.

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APPENDIX A.--DATA TABLES

Table A1.--Field measurements and concentrations of bacteria

Abbreviations:

deg C, degrees Celsius;

μS/cm, microsiemens per centimeter at 25 degrees Celsius;

K, in front of bacteria concentration denotes nonideal number of colonies on counting plate;

cols. per 100 ml, colonies per 100 milliliters;

mg/L, milligrams per liter;

US, unconsolidated sedimentary aquifer;

TG, Troutdale gravel aquifer;

UF, undifferentiated fine-grained unit;

TS, Troutdale sandstone aquifer;

BR, older rocks unit

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Lat-i-tude	Long-i-tude	Date	Time	Geo-hydro-logic unit	Elevation of land surface datum (feet above NGVD)	Depth of well total (feet)
01N/03E-03A02	45 36 16 N	122 24 47 W	05-17-88	1415	BR	230	140
01N/03E-08B01	45 35 22 N	122 27 46 W	05-13-88	1310	TG	435	420
01N/03E-10C01	45 35 33 N	122 25 28 W	05-26-88	1625	[a]TS	615	140
01N/03E-12L04	45 35 04 N	122 23 11 W	04-27-88	0910	US	34	87
			08-02-88	1315	US	34	87
01N/04E-03G01	45 36 04 N	122 17 54 W	05-18-88	1255	TG	705	147
01N/04E-08K05	45 35 01 N	122 20 23 W	04-27-88	1105	US	85	120
02N/01E-04C01	45 41 23 N	122 41 37 W	05-13-88	0900	TG	215	303
02N/01E-07M01	45 40 13 N	122 44 32 W	05-25-88	1245	US	20	175
02N/01E-09K01	45 40 18 N	122 41 24 W	05-11-88	1340	US	50	135
			08-02-88	1200	US	50	135
02N/01E-15A02	45 39 43 N	122 39 39 W	05-26-88	1350	TG	173	244
02N/01E-15Q01	45 39 08 N	122 40 14 W	05-03-88	1310	US	215	278
			07-20-88	1010	US	215	278
02N/01E-23Q03	45 38 08 N	122 38 48 W	04-28-88	1230	TG	222	280
			07-20-88	0940	TG	222	280
02N/01E-24G01	45 38 36 N	122 37 31 W	05-12-88	0950	TG	170	167
02N/01E-27M09	45 37 35 N	122 40 48 W	05-25-88	1545	US	42	128
			08-02-88	1105	US	42	128
02N/01E-36B09	45 37 08 N	122 37 31 W	04-28-88	1040	US	55	112
			07-20-88	0910	US	55	112
02N/02E-06D01	45 41 27 N	122 36 53 W	05-10-88	1255	US	260	40
02N/02E-07A02	45 40 41 N	122 36 07 W	04-27-88	1410	TG	270	194
			04-27-88	1415	TG	270	194
			08-02-88	0845	TG	270	194
02N/02E-10N03	45 40 03 N	122 33 23 W	05-12-88	1350	TG	220	109
02N/02E-14R04	45 39 06 N	122 31 12 W	05-13-88	0825	TG	266	236
02N/02E-21M02	45 38 22 N	122 34 33 W	05-12-88	1145	TG	185	90
02N/02E-27D02	45 38 00 N	122 33 15 W	04-28-88	0830	TG	314	327
			07-20-88	1100	TG	314	327
02N/02E-35M02	45 36 50 N	122 31 57 W	05-13-88	1050	TG	302	254
02N/03E-06M01	45 41 10 N	122 29 36 W	04-26-88	1600	TG	245	116
			08-02-88	1645	TG	245	116
			08-02-88	1650	TG	245	116
02N/03E-09Q01	45 40 01 N	122 26 20 W	05-09-88	1235	TG	350	143
02N/03E-12P02	45 39 58 N	122 23 11 W	05-09-88	1515	BR	958	560
			08-02-88	1505	BR	958	560
02N/03E-21R02	45 38 21 N	122 26 15 W	05-17-88	0850	TG	286	101
			05-17-88	0855	TG	286	101
			08-02-88	1555	TG	286	101

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Temperature water (deg C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Coliform total (cols. per 100 ml)	Coliform, fecal (cols. per 100 ml)	Streptococci, fecal (cols. per 100 ml)
01N/03E-03A02	12.0	207	7.4	10.4	<1	<1	<1
01N/03E-08B01	12.0	158	7.6	8.8	<1	<1	<1
01N/03E-10C01	12.5	161	6.8	7.2	<1	<1	<1
01N/03E-12L04	12.0	82	6.8	5.9	<1	<1	22
	--	--	--	--	<1	<1	<1
01N/04E-03G01	11.5	94	6.7	8.6	<1	<1	<1
01N/04E-08K05	11.5	52	6.6	7.2	<1	<1	<1
02N/01E-04C01	12.0	292	6.6	7.5	<1	<1	<1
02N/01E-07M01	13.5	360	7.7	0.0	<1	<1	<1
02N/01E-09K01	15.5	258	7.1	7.2	9	<1	<1
	--	--	--	--	<1	<1	<1
02N/01E-15A02	12.5	265	7.1	5.9	<1	<1	<1
02N/01E-15Q01	12.5	275	7.2	5.3	<1	<1	3
	--	--	--	--	<1	<1	<1
02N/01E-23Q03	15.0	248	7.2	5.7	<1	<1	>200
	--	--	--	--	<1	<1	<1
02N/01E-24G01	13.0	233	6.6	5.4	<1	<1	<1
02N/01E-27M09	13.5	247	7.0	4.6	1	<1	<1
	--	--	--	--	<1	<1	<1
02N/01E-36B09	13.0	222	6.7	5.8	<1	<1	25
	12.5	232	6.5	6.5	<1	<1	<1
02N/02E-06D01	14.5	229	6.8	4.4	<1	<1	<1
02N/02E-07A02	12.0	282	6.6	4.2	<1	<1	10
	12.0	282	6.6	4.2	<1	<1	<1
	--	--	--	--	<1	<1	<1
02N/02E-10N03	12.5	213	6.9	7.4	<1	<1	<1
02N/02E-14R04	11.0	187	7.0	6.8	<1	<1	<1
02N/02E-21M02	13.5	206	6.8	5.8	<1	<1	<1
02N/02E-27D02	11.0	161	7.3	4.3	<1	<1	22
	--	--	--	--	<1	<1	<1
02N/02E-35M02	13.0	184	6.8	7.6	<1	<1	<1
02N/03E-06M01	12.5	136	7.3	4.9	<1	<1	K120
	--	--	--	--	<1	<1	<1
	--	--	--	--	1	<1	<1
02N/03E-09Q01	11.5	157	7.7	4.0	<1	<1	<1
02N/03E-12P02	11.0	113	7.3	5.4	1	<1	<1
	--	--	--	--	<1	<1	<1
02N/03E-21R02	11.5	135	7.8	7.4	<1	<1	1
	11.5	135	7.8	7.4	<1	<1	<1
	--	--	--	--	K150	<1	K100

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Latitude	Longitude	Date	Time	Geohydrologic unit	Elevation of land surface datum (feet above NGVD)	Depth of well total (feet)
02N/03E-28Q01	45 37 22 N	122 26 36 W	05-26-88	1105	TS	265	160
02N/03E-30Q02	45 37 18 N	122 28 57 W	05-25-88	1030	TS	285	388
02N/04E-27N01	45 37 27 N	122 18 20 W	05-18-88	0855	BR	182	143
			08-02-88	1415	BR	182	143
02N/04E-31G01	45 37 02 N	122 21 42 W	05-17-88	1215	BR	140	200
02N/04E-36N01	45 36 34 N	122 15 53 W	05-18-88	1105	TG	1,050	65
03N/01E-06H02	45 46 32 N	122 43 21 W	05-11-88	1440	TG	215	231
			08-03-88	0945	TG	215	231
03N/01E-11D01	45 45 54 N	122 39 23 W	05-16-88	1355	TG	270	145
03N/01E-17P01	45 44 11 N	122 42 46 W	04-30-88	0905	TG	174	187
			04-30-88	0910	TG	174	187
03N/01E-22D02	45 44 06 N	122 40 50 W	05-16-88	0905	TG	191	196
03N/01E-27P01	45 42 37 N	122 40 20 W	05-13-88	1110	US	25	65
			07-19-88	0755	US	25	65
03N/01E-30J01	45 42 45 N	122 43 21 W	05-16-88	1125	TG	135	193
			08-03-88	0900	TG	135	193
03N/01E-35B02	45 42 21 N	122 38 45 W	04-26-88	0845	TG	110	172
			07-19-88	0820	TG	110	172
03N/02E-01C02	45 46 47 N	122 30 33 W	05-24-88	1350	BR	345	112
03N/02E-03B01	45 46 50 N	122 32 31 W	04-25-88	1230	TG	290	144
			07-19-88	1505	TG	290	144
03N/02E-05E02	45 46 23 N	122 35 47 W	05-11-88	0845	TG	223	112
			05-11-88	0850	TG	223	112
03N/02E-10R01	45 45 15 N	122 32 23 W	05-10-88	0920	TS	273	270
03N/02E-20H01	45 43 59 N	122 34 42 W	04-28-88	1550	UF	256	248
03N/02E-23H01	45 43 56 N	122 30 57 W	05-24-88	1610	TG	295	194
03N/02E-35D02	45 42 26 N	122 32 03 W	04-26-88	1055	TS	280	290
			07-19-88	0925	TS	280	290
03N/03E-03P01	45 46 01 N	122 25 34 W	04-26-88	1310	BR	420	72
			07-19-88	1040	BR	420	72
03N/03E-34R01	45 41 42 N	122 24 47 W	05-09-88	1020	BR	341	385
04N/01E-07H01	45 50 48 N	122 43 29 W	05-11-88	0910	UF	247	367
			05-11-88	0915	UF	247	367
04N/01E-10E01	45 50 53 N	122 40 49 W	05-12-88	1550	UF	279	338
			07-19-88	1720	UF	279	338
04N/01E-13B01	45 50 15 N	122 37 28 W	05-17-88	1220	UF	165	142
			07-20-88	1545	UF	165	142
04N/01E-18J01	45 49 39 N	122 43 29 W	05-11-88	1215	BR	250	445
04N/01E-19F02	45 49 02 N	122 44 03 W	04-29-88	0940	UF	40	208
			07-20-88	1440	UF	40	208

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Temperature water (deg C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Coliform total (cols. per 100 ml)	Coliform, fecal (cols. per 100 ml)	Streptococci, fecal (cols. per 100 ml)
02N/03E-28Q01	11.5	168	8.7	4.2	<1	<1	<1
02N/03E-30Q02	13.0	167	8.2	0.1	<1	<1	<1
02N/04E-27N01	12.0	123	7.1	4.4	<1	<1	50
	--	--	--	--	<1	<1	<1
02N/04E-31G01	12.5	438	9.5	2.1	<1	<1	<1
02N/04E-36N01	9.5	14	5.7	10.2	<1	<1	<1
03N/01E-06H02	14.0	285	7.2	1.2	51	<1	<1
	--	--	--	--	<1	<1	<1
03N/01E-11D01	12.0	177	6.6	1.7	<1	<1	<1
03N/01E-17P01	10.0	360	7.5	0.3	<1	<1	<1
	10.0	360	7.5	0.3	<1	<1	<1
03N/01E-22D02	13.0	305	7.2	0.0	<1	<1	<1
03N/01E-27P01	12.0	267	6.7	3.9	2	<1	<1
	--	--	--	--	<1	<1	<1
03N/01E-30J01	12.0	302	6.8	3.9	<1	<1	1
	--	--	--	--	<1	<1	<1
03N/01E-35B02	12.0	191	7.2	4.8	<1	<1	25
	--	--	--	--	<1	<1	<1
03N/02E-01C02	12.5	115	9.4	0.1	<1	<1	<1
03N/02E-03B01	12.5	215	7.2	5.8	1	<1	48
	14.5	232	6.9	6.8	<1	<1	<1
03N/02E-05E02	12.0	133	6.9	6.1	<1	<1	<1
	12.0	133	6.9	6.1	<1	<1	<1
03N/02E-10R01	12.5	262	7.3	1.5	<1	<1	<1
03N/02E-20H01	11.5	183	7.3	0.1	<1	<1	<1
03N/02E-23H01	13.0	252	7.2	0.0	<1	<1	<1
03N/02E-35D02	13.0	172	7.2	0.3	<1	<1	<1
	13.0	177	7.0	0.3	6	<1	<1
03N/03E-03P01	12.0	109	6.8	6.9	<1	<1	K120
	12.0	113	6.8	6.3	<1	<1	<1
03N/03E-34R01	14.5	177	8.2	8.0	<1	<1	<1
04N/01E-07H01	13.0	240	6.8	6.3	<1	<1	<1
	13.0	240	6.8	6.3	<1	<1	<1
04N/01E-10E01	15.0	188	7.3	0.0	12	<1	<1
	--	--	--	--	<1	<1	<1
04N/01E-13B01	12.5	290	6.9	3.4	5	<1	<1
	--	--	--	--	<1	<1	<1
04N/01E-18J01	15.5	367	8.5	0.2	<1	<1	<1
04N/01E-19F02	11.5	222	7.1	1.6	<1	<1	5
	--	--	--	--	<1	<1	<1

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Lat-i-tude	Long-i-tude	Date	Time	Geo-hydro-logic unit	Elevation of land surface datum (feet above NGVD)	Depth of well total (feet)
04N/01E-25L01	45 47 58 N	122 37 58 W	05-18-88	0805	UF	261	216
			05-18-88	0810	UF	261	216
			07-19-88	1610	UF	261	216
04N/01E-33B02	45 47 29 N	122 41 27 W	04-30-88	1240	[b]UF	229	170
04N/02E-02A02	45 51 58 N	122 30 59 W	05-16-88	1545	BR	498	200
04N/02E-06K01	45 51 21 N	122 36 26 W	05-18-88	1340	TG	502	160
04N/02E-10N01	45 50 31 N	122 33 20 W	04-25-88	1520	TG	525	89
04N/02E-23B02	45 49 28 N	122 31 22 W	05-24-88	1910	UF	442	322
04N/02E-29A02	45 48 28 N	122 34 46 W	05-18-88	1120	UF	100	200
04N/03E-02D02	45 51 52 N	122 24 36 W	04-25-88	0930	US	700	80
			07-19-88	1345	US	700	80
04N/03E-28R02	45 47 57 N	122 26 16 W	05-13-88	1345	BR	662	435
			07-19-88	1125	BR	662	435
04N/03E-29L01	45 47 59 N	122 28 06 W	05-18-88	1605	UF	545	298
05N/01E-10F01	45 55 59 N	122 40 29 W	05-12-88	1320	US	56	86
			08-03-88	1300	US	56	86
			08-03-88	1305	US	56	86
05N/01E-13N01	45 54 42 N	122 37 58 W	05-10-88	1205	BR	623	227
05N/01E-15E01	45 55 14 N	122 40 40 W	05-10-88	0920	TG	495	100
05N/01E-17E01	45 55 03 N	122 42 58 W	05-12-88	1115	BR	92	110
05N/01E-25N01D1	45 53 02 N	122 38 16 W	05-10-88	1415	TG	638	130
05N/01E-29H01	45 53 25 N	122 42 05 W	05-12-88	0840	BR	635	260
			08-03-88	1210	BR	635	260
05N/01E-34G04	45 52 25 N	122 39 50 W	04-29-88	1150	UF	410	257
			08-03-88	1055	UF	410	257
05N/02E-08B01	45 56 17 N	122 34 55 W	05-03-88	1015	BR	183	210
05N/02E-15K01	45 55 00 N	122 32 31 W	05-16-88	1325	UF	741	200
05N/02E-21R01	45 53 56 N	122 33 33 W	05-17-88	1000	BR	835	345
05N/03E-12P01	45 55 33 N	122 22 43 W	05-16-88	0935	US	497	115
05N/03E-16P01	45 54 37 N	122 26 41 W	05-17-88	0750	BR	407	31
05N/03E-27N02	45 53 00 N	122 25 42 W	05-24-88	1145	BR	838	240
06N/03E-34H02	45 57 37 N	122 24 39 W	05-24-88	0925	BR	1,155	360

Table A1.--Field measurements and concentrations of bacteria--Continued

Local well number	Temperature water (deg C)	Specific conductance (µS/cm)	pH (standard units)	Oxygen, dissolved (mg/L)	Coliform total (cols. per 100 ml)	Coliform, fecal (cols. per 100 ml)	Streptococci, fecal (cols. per 100 ml)
04N/01E-25L01	10.0	172	6.7	1.8	8	<1	<1
	10.0	172	6.7	1.8	7	<1	<1
	--	--	--	--	<1	<1	<1
04N/01E-33B02	13.0	235	6.9	0.3	<1	<1	<1
04N/02E-02A02	11.5	182	7.9	0.0	<1	<1	<1
04N/02E-06K01	11.5	70	6.7	8.4	<1	<1	<1
04N/02E-10N01	11.0	102	6.5	7.7	<1	<1	<1
04N/02E-23B02	12.0	51	7.2	6.9	<1	<1	<1
04N/02E-29A02	11.0	78	7.2	0.0	<1	<1	<1
04N/03E-02D02	11.0	101	7.0	9.2	<1	<1	<1
	12.0	116	6.6	9.2	<1	<1	<1
04N/03E-28R02	12.5	136	8.3	3.8	20	<1	<1
	--	--	--	--	<1	<1	<1
04N/03E-29L01	12.0	287	7.6	0.0	<1	<1	<1
05N/01E-10F01	12.5	125	6.8	0.0	17	<1	<1
	--	--	--	--	<1	<1	<1
	--	--	--	--	<1	<1	<1
05N/01E-13N01	13.0	252	7.8	6.5	<1	<1	<1
05N/01E-15E01	15.0	81	6.3	7.1	<1	<1	<1
05N/01E-17E01	12.5	313	7.6	0.0	<1	<1	<1
05N/01E-25N01D1	14.0	83	6.7	5.7	<1	<1	<1
05N/01E-29H01	13.0	119	6.5	3.9	1	<1	<1
	--	--	--	--	5	<1	<1
05N/01E-34G04	12.0	138	6.7	5.1	<1	<1	30
	--	--	--	--	<1	<1	<1
05N/02E-08B01	11.5	137	7.4	6.6	<1	<1	<1
05N/02E-15K01	10.5	106	6.7	7.5	<1	<1	<1
05N/02E-21R01	12.5	183	9.3	2.8	<1	<1	<1
05N/03E-12P01	10.5	87	6.6	6.9	<1	<1	<1
05N/03E-16P01	10.5	83	6.3	6.8	<1	<1	<1
05N/03E-27N02	11.0	118	8.2	6.8	<1	<1	<1
06N/03E-34H02	11.0	102	8.4	4.3	<1	<1	<1

[a] Also partly open to confining unit 2.

[b] Also partly open to TG.

Table A2.--Values and concentrations of common constituents and radon

[deg C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °Celsius; mg/L, milligrams per liter; NTU, nephelometric turbidity units; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Local well number	Date	Temperature water (deg C)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Oxygen, dissolved (mg/L)	Turbidity (NTU)	Hardness total (mg/L as $CaCO_3$)
01N/03E-03A02	05-17-88	12.0	207	206	7.4	7.6	10.4	0.1	93
01N/03E-08B01	05-13-88	12.0	158	150	7.6	7.6	8.8	0.1	64
01N/03E-10C01	05-26-88	12.5	161	185	6.8	7.1	7.2	0.3	79
01N/03E-12L04	04-27-88	12.0	82	86	6.8	6.9	5.9	0.3	30
01N/04E-03G01	05-18-88	11.5	94	97	6.7	7.0	8.6	0.3	35
01N/04E-08K05	04-27-88	11.5	52	52	6.6	7.3	7.2	0.3	19
02N/01E-04C01	05-13-88	12.0	292	289	6.6	6.8	7.5	0.2	120
02N/01E-07M01	05-25-88	13.5	360	362	7.7	7.9	0.0	1.2	180
02N/01E-09K01	05-11-88	15.5	258	255	7.1	7.3	7.2	0.2	120
02N/01E-15A02	05-26-88	12.5	265	269	7.1	7.3	5.9	0.2	120
02N/01E-15Q01	05-03-88	12.5	275	282	7.2	7.5	5.3	0.2	120
02N/01E-23Q03	04-28-88	15.0	248	255	7.2	7.4	5.7	0.2	110
02N/01E-24G01	05-12-88	13.0	233	236	6.6	6.8	5.4	0.7	98
02N/01E-27M09	05-25-88	13.5	247	250	7.0	7.2	4.6	0.2	100
02N/01E-36B09	04-28-88	13.0	222	227	6.7	6.9	5.8	0.3	92
02N/02E-06D01	05-10-88	14.5	229	231	6.8	7.0	4.4	0.1	97
02N/02E-07A02	04-27-88	12.0	282	299	6.6	6.8	4.2	0.2	130
	04-27-88	12.0	282	298	6.6	6.8	4.2	0.2	130
02N/02E-10N03	05-12-88	12.5	213	210	6.9	7.2	7.4	0.1	86
02N/02E-14R04	05-13-88	11.0	187	190	7.0	7.3	6.8	0.1	78
02N/02E-21M02	05-12-88	13.5	206	208	6.8	7.0	5.8	0.2	87
02N/02E-27D02	04-28-88	11.0	161	166	7.3	7.4	4.3	0.3	70
02N/02E-35M02	05-13-88	13.0	184	185	6.8	7.0	7.6	0.8	73
02N/03E-06M01	04-26-88	12.5	136	140	7.3	7.4	4.9	0.3	54
02N/03E-09Q01	05-09-88	11.5	157	159	7.7	7.8	4.0	0.2	63
02N/03E-12P02	05-09-88	11.0	113	112	7.3	7.2	5.4	2.6	43
02N/03E-21R02	05-17-88	11.5	135	136	7.8	7.9	7.4	0.2	53
	05-17-88	11.5	135	136	7.8	8.0	7.4	0.2	53
02N/03E-28Q01	05-26-88	11.5	168	173	8.7	8.5	4.2	0.2	73
02N/03E-30Q02	05-25-88	13.0	167	188	8.2	8.2	0.1	0.2	75
02N/04E-27N01	05-18-88	12.0	123	126	7.1	7.7	4.4	2.6	43
02N/04E-31G01	05-17-88	12.5	438	426	9.5	9.2	2.1	2.0	43
02N/04E-36N01	05-18-88	9.5	14	14	5.7	5.8	10.2	0.2	3
03N/01E-06H02	05-11-88	14.0	285	291	7.2	7.3	1.2	0.6	140
03N/01E-11D01	05-16-88	12.0	177	179	6.6	6.9	1.7	2.1	73
03N/01E-17P01	04-30-88	10.0	360	381	7.5	7.5	0.3	0.2	190
	04-30-88	10.0	360	381	7.5	7.5	0.3	0.3	190
03N/01E-22D02	05-16-88	13.0	305	301	7.2	7.4	0.0	7.8	140
03N/01E-27P01	05-13-88	12.0	267	268	6.7	6.9	3.9	0.1	120
03N/01E-30J01	05-16-88	12.0	302	304	6.8	7.1	3.9	5.1	140

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Hardness noncarbonate total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium percent	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate field (mg/L as HCO_3)
01N/03E-03A02	0	19	11	7.7	15	0.4	1.7	122
01N/03E-08B01	0	11	8.8	6.7	18	0.4	1.8	84
01N/03E-10C01	0	16	9.6	7.8	17	0.4	1.9	113
01N/03E-12L04	0	8.4	2.2	3.7	20	0.3	1.4	38
01N/04E-03G01	0	7.9	3.7	5.2	23	0.4	1.8	60
01N/04E-08K05	0	4.8	1.6	2.5	22	0.3	0.6	24
02N/01E-04C01	29	30	12	7.7	12	0.3	2.3	116
02N/01E-07M01	0	49	14	7.5	8	0.3	4.2	242
02N/01E-09K01	8	31	9.7	6.4	10	0.3	2.6	133
02N/01E-15A02	2	33	10	6.3	10	0.3	2.2	149
02N/01E-15Q01	15	33	10	6.9	10	0.3	3.7	133
02N/01E-23Q03	13	30	9.2	6.1	10	0.3	3.4	122
02N/01E-24G01	19	21	11	6.4	12	0.3	3.3	96
02N/01E-27M09	9	27	8.9	8.3	14	0.4	3.5	116
02N/01E-36B09	15	23	8.4	6.5	13	0.3	4.5	94
02N/02E-06D01	5	23	9.6	6.2	12	0.3	2.7	112
02N/02E-07A02	24	32	13	7.7	11	0.3	2.9	134
	25	32	13	7.5	11	0.3	2.9	133
02N/02E-10N03	13	21	8.1	5.8	12	0.3	3.3	89
02N/02E-14R04	10	19	7.4	5.5	13	0.3	3.4	83
02N/02E-21M02	0	21	8.5	5.9	12	0.3	2.6	107
02N/02E-27D02	2	15	7.9	5.7	15	0.3	2.3	83
02N/02E-35M02	5	17	7.5	7.1	17	0.4	2.3	83
02N/03E-06M01	0	11	6.5	6.8	21	0.4	1.9	83
02N/03E-09Q01	0	17	4.9	9.7	25	0.6	1.1	98
02N/03E-12P02	0	13	2.5	6.1	24	0.4	0.1	70
02N/03E-21R02	0	12	5.7	7.8	23	0.5	1.7	84
	0	12	5.6	7.7	23	0.5	1.7	84
02N/03E-28Q01	0	16	8.0	7.7	18	0.4	1.9	96
02N/03E-30Q02	0	16	8.5	10	22	0.5	2.6	118
02N/04E-27N01	0	15	1.4	8.5	30	0.6	0.2	90
02N/04E-31G01	15	16	0.67	62	75	4	1.7	13
02N/04E-36N01	0	0.57	0.43	1.1	41	0.3	0.2	6
03N/01E-06H02	0	32	14	9.1	12	0.3	1.9	184
03N/01E-11D01	0	18	6.9	7.8	18	0.4	2.0	105
03N/01E-17P01	0	52	14	8.2	8	0.3	4.0	245
	0	52	14	8.0	8	0.3	3.9	249
03N/01E-22D02	0	31	15	9.1	12	0.3	2.7	193
03N/01E-27P01	3	29	11	7.5	12	0.3	2.6	140
03N/01E-30J01	2	31	15	8.8	12	0.3	2.4	168

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Carbonate field (mg/L as CO_3)	Alkalinity, field (mg/L - $CaCO_3$)	Alkalinity lab (mg/L as $CaCO_3$)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
01N/03E-03A02	0	100	99	7.7	6.1	1.7	0.3	53
01N/03E-08B01	0	69	69	3.4	2.2	2.7	0.3	55
01N/03E-10C01	0	93	92	28	0.9	1.7	0.3	55
01N/03E-12L04	0	31	32	9.6	3.1	2.6	0.1	27
01N/04E-03G01	0	49	45	19	0.6	1.3	0.2	53
01N/04E-08K05	0	20	20	9.6	1.5	1.1	0.1	19
02N/01E-04C01	0	95	92	46	19	5.6	0.3	63
02N/01E-07M01	0	198	193	7.7	1.6	1.3	0.3	45
02N/01E-09K01	0	109	104	17	10	5.2	0.2	50
02N/01E-15A02	0	122	119	19	8.1	4.1	0.3	47
02N/01E-15Q01	0	109	110	13	12	5.4	0.2	50
02N/01E-23Q03	0	100	100	12	11	4.7	0.2	49
02N/01E-24G01	0	79	79	38	14	7.3	0.3	58
02N/01E-27M09	0	95	94	18	16	5.7	0.3	41
02N/01E-36B09	0	77	78	30	14	5.1	0.2	50
02N/02E-06D01	0	92	87	28	7.2	7.9	0.2	44
02N/02E-07A02	0	110	111	53	7.6	13	0.1	43
	0	109	111	53	7.8	12	0.1	43
02N/02E-10N03	0	73	73	18	7.3	6.0	0.2	50
02N/02E-14R04	0	68	68	13	6.6	4.6	0.3	50
02N/02E-21M02	0	88	84	27	7.9	3.7	0.2	42
02N/02E-27D02	0	68	68	6.6	4.6	3.0	0.1	53
02N/02E-35M02	0	68	67	21	7.2	4.7	1.0	48
02N/03E-06M01	0	68	66	6.6	1.4	1.4	0.2	57
02N/03E-09Q01	0	80	81	3.1	0.7	1.4	0.1	46
02N/03E-12P02	0	57	55	5.6	<0.2	1.8	0.1	40
02N/03E-21R02	0	69	69	2.1	0.5	1.3	0.3	45
	0	69	69	2.1	0.5	1.3	0.3	45
02N/03E-28Q01	7	91	88	0.3	1.0	1.4	0.2	27
02N/03E-30Q02	0	97	95	1.2	2.2	1.6	0.2	36
02N/04E-27N01	0	74	56	11	2.4	2.3	0.2	26
02N/04E-31G01	10	27	24	0.0	2.4	110	0.3	15
02N/04E-36N01	0	5.0	4.0	19	<0.2	1.2	0.1	8.4
03N/01E-06H02	0	151	150	18	0.7	2.7	0.4	65
03N/01E-11D01	0	86	87	42	1.4	2.3	0.3	64
03N/01E-17P01	0	201	201	12	<0.2	2.1	0.5	47
	0	204	202	13	<0.2	2.0	0.4	47
03N/01E-22D02	0	158	158	19	3.4	3.3	0.4	54
03N/01E-27P01	0	115	107	44	8.9	6.4	0.3	56
03N/01E-30J01	0	138	136	42	12	4.3	0.4	62

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Solids, residue at 180 deg. C, dis- solved (mg/L)	Solids, sum of consti- tuents, dis- solved (mg/L)	Nitro- gen, NO2+NO3, dis- solved (mg/L as N)	Phos- phorous, dis- solved (mg/L as P)	Alum- inum, dis- solved (µg/L as Al)	Iron, dis- solved (µg/L as Fe)	Manga- nese, dis- solved (µg/L as Mn)	Radon 222 total (pCi/L)
01N/03E-03A02	152	161	0.14	0.05	<10	3	14	230
01N/03E-08B01	130	137	1.6	0.14	<10	4	<1	<80
01N/03E-10C01	139	150	0.32	0.06	<10	13	2	580
01N/03E-12L04	67	69	0.31	0.03	<10	5	<1	610
01N/04E-03G01	90	103	<0.10	0.04	<10	<3	2	370
01N/04E-08K05	41	45	0.45	0.02	<10	<3	<1	600
02N/01E-04C01	225	226	6.7	0.14	<10	5	4	540
02N/01E-07M01	224	242	<0.10	0.18	<10	180	250	84
02N/01E-09K01	181	192	2.6	0.12	<10	<3	<1	420
02N/01E-15A02	182	192	1.7	0.21	<10	39	2	320
02N/01E-15Q01	196	202	3.5	0.13	<10	<3	<1	190
02N/01E-23Q03	180	187	3.0	0.10	<10	<3	<1	130
02N/01E-24G01	179	185	3.7	0.07	<10	120	4	270
02N/01E-27M09	167	177	2.0	0.07	<10	12	12	250
02N/01E-36B09	163	171	2.9	0.08	<10	<3	<1	180
02N/02E-06D01	158	168	2.8	0.07	<10	<3	<1	480
02N/02E-07A02	190	199	3.1	0.05	<10	<3	<1	630
	191	197	3.1	0.05	<10	3	<1	660
02N/02E-10N03	162	164	4.1	0.07	<10	4	<1	140
02N/02E-14R04	143	153	3.4	0.07	<10	<3	<1	320
02N/02E-21M02	144	154	2.2	0.03	<10	14	1	530
02N/02E-27D02	132	139	1.6	0.08	<10	<3	1	400
02N/02E-35M02	135	146	2.3	0.06	<10	15	5	260
02N/03E-06M01	120	128	0.31	0.20	<10	<3	<1	140
02N/03E-09Q01	116	129	<0.10	0.06	<10	<3	<1	100
02N/03E-12P02	95	98	<0.10	0.02	<10	<3	17	<80
02N/03E-21R02	101	116	<0.10	0.03	<10	<3	<1	490
	106	115	<0.10	0.04	<10	<3	<1	480
02N/03E-28Q01	108	125	<0.10	0.04	<10	<3	2	110
02N/03E-30Q02	120	135	<0.10	0.09	<10	6	93	280
02N/04E-27N01	90	100	<0.10	<0.01	<10	26	<1	300
02N/04E-31G01	245	235	<0.10	0.02	<10	4	2	120
02N/04E-36N01	12	15	0.10	0.03	<10	41	2	<80
03N/01E-06H02	--	217	0.25	0.14	<10	7	64	670
03N/01E-11D01	148	157	0.58	0.03	<10	16	2	140
03N/01E-17P01	236	249	<0.10	0.34	<10	36	510	290
	238	250	<0.10	0.33	<10	33	510	320
03N/01E-22D02	200	215	<0.10	0.12	<10	1300	140	530
03N/01E-27P01	191	205	3.2	0.14	50	<3	<1	260
03N/01E-30J01	215	226	1.6	0.03	<10	14	2	400

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Date	Temperature water (deg C)	Specific conductance (μS/cm)	Specific conductance lab (μS/cm)	pH (standard units)	pH lab (standard units)	Oxygen, dissolved (mg/L)	Turbidity (NTU)	Hardness total (mg/L as $CaCO_3$)
03N/01E-35B02	04-26-88	12.0	191	203	7.2	7.2	4.8	0.3	88
03N/02E-01C02	05-24-88	12.5	115	117	9.4	9.2	0.1	0.2	8
03N/02E-03B01	04-25-88	12.5	215	214	7.2	7.4	5.8	0.3	96
03N/02E-05E02	05-11-88	12.0	133	134	6.9	7.2	6.1	0.1	54
	05-11-88	12.0	133	134	6.9	7.1	6.1	0.1	54
03N/02E-10R01	05-10-88	12.5	262	268	7.3	7.5	1.5	0.1	130
03N/02E-20H01	04-28-88	11.5	183	183	7.3	7.4	0.1	1.5	73
03N/02E-23H01	05-24-88	13.0	252	256	7.2	7.6	0.0	0.7	110
03N/02E-35D02	04-26-88	13.0	172	177	7.2	7.9	0.3	0.3	73
03N/03E-03P01	04-26-88	12.0	109	113	6.8	7.6	6.9	0.3	48
03N/03E-34R01	05-09-88	14.5	177	180	8.2	8.1	8.0	0.2	66
04N/01E-07H01	05-11-88	13.0	240	248	6.8	6.9	6.3	0.1	110
	05-11-88	13.0	240	246	6.8	7.0	6.3	0.2	110
04N/01E-10E01	05-12-88	15.0	188	191	7.3	7.5	0.0	6.0	74
04N/01E-13B01	05-17-88	12.5	290	291	6.9	7.2	3.4	0.3	110
04N/01E-18J01	05-11-88	15.5	367	373	8.5	8.3	0.2	0.6	29
04N/01E-19F02	04-29-88	11.5	222	232	7.1	7.1	1.6	0.3	100
04N/01E-25L01	05-18-88	10.0	172	180	6.7	7.0	1.8	1.9	75
	05-18-88	10.0	172	180	6.7	6.9	1.8	2.4	75
04N/01E-33B02	04-30-88	13.0	235	240	6.9	7.0	0.3	0.3	110
04N/02E-02A02	05-16-88	11.5	182	191	7.9	8.1	0.0	5.6	48
04N/02E-06K01	05-18-88	11.5	70	72	6.7	6.9	8.4	0.3	25
04N/02E-10N01	04-25-88	11.0	102	108	6.5	6.6	7.7	0.2	40
04N/02E-23B02	05-24-88	12.0	51	53	7.2	7.3	6.9	0.2	17
04N/02E-29A02	05-18-88	11.0	78	81	7.2	7.3	0.0	1.3	29
04N/03E-02D02	04-25-88	11.0	101	106	7.0	7.4	9.2	0.3	39
04N/03E-28R02	05-13-88	12.5	136	140	8.3	8.2	3.8	0.3	29
04N/03E-29L01	05-18-88	12.0	287	297	7.6	7.8	0.0	5.6	85
05N/01E-10F01	05-12-88	12.5	125	103	6.8	6.7	0.0	32	39
05N/01E-13N01	05-10-88	13.0	252	256	7.8	7.9	6.5	0.3	61
05N/01E-15E01	05-10-88	15.0	81	83	6.3	6.4	7.1	3.0	25
05N/01E-17E01	05-12-88	12.5	313	326	7.6	7.8	0.0	0.6	120
05N/01E-25N01D1	05-10-88	14.0	83	83	6.7	7.1	5.7	75	27
05N/01E-29H01	05-12-88	13.0	119	122	6.5	6.7	3.9	18	35
05N/01E-34G04	04-29-88	12.0	138	143	6.7	6.8	5.1	0.3	51
05N/02E-08B01	05-03-88	11.5	137	144	7.4	7.6	6.6	0.3	40
05N/02E-15K01	05-16-88	10.5	106	107	6.7	7.3	7.5	1.0	40
05N/02E-21R01	05-17-88	12.5	183	178	9.3	9.3	2.8	2.6	7
05N/03E-12P01	05-16-88	10.5	87	89	6.6	6.8	6.9	0.2	35
05N/03E-16P01	05-17-88	10.5	83	83	6.3	7.0	6.8	0.2	29

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Hardness noncarbonate total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium percent	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate field (mg/L as HCO_3)
03N/01E-35B02	0	22	8.1	6.0	13	0.3	2.0	110
03N/02E-01C02	0	3.1	0.02	24	87	4	0.1	49
03N/02E-03B01	0	23	9.4	9.4	17	0.4	1.6	134
03N/02E-05E02	0	13	5.2	6.5	20	0.4	1.3	76
	0	13	5.3	6.9	21	0.4	1.2	76
03N/02E-10R01	0	33	11	7.2	11	0.3	1.3	166
03N/02E-20H01	0	17	7.5	6.7	16	0.4	2.4	104
03N/02E-23H01	0	24	12	12	19	0.5	3.0	162
03N/02E-35D02	0	16	8.0	8.3	19	0.4	2.6	109
03N/03E-03P01	0	12	4.3	5.0	18	0.3	0.3	68
03N/03E-34R01	0	23	2.1	12	28	0.7	0.3	111
04N/01E-07H01	0	24	11	11	18	0.5	2.5	150
	0	24	11	11	18	0.5	2.4	149
04N/01E-10E01	0	20	5.9	10	22	0.5	1.2	111
04N/01E-13B01	12	27	9.9	17	25	0.7	0.7	117
04N/01E-18J01	0	8.6	1.8	70	80	6	6.6	164
04N/01E-19F02	0	22	11	9.4	17	0.4	2.0	143
04N/01E-25L01	0	17	7.9	7.1	17	0.4	1.9	110
	0	17	7.8	7.1	17	0.4	1.9	109
04N/01E-33B02	0	26	10	9.1	16	0.4	0.2	149
04N/02E-02A02	0	14	3.2	23	51	1	0.5	121
04N/02E-06K01	0	5.9	2.5	4.4	26	0.4	1.7	41
04N/02E-10N01	0	10	3.6	6.3	25	0.4	1.7	60
04N/02E-23B02	0	5.4	0.97	3.1	27	0.3	0.3	24
04N/02E-29A02	0	7.5	2.6	3.8	21	0.3	0.7	43
04N/03E-02D02	0	11	2.9	5.1	22	0.4	0.5	63
04N/03E-28R02	0	11	0.28	21	61	2	0.1	82
04N/03E-29L01	0	22	7.2	33	46	2	1.0	192
05N/01E-10F01	0	8.2	4.4	5.9	24	0.4	1.2	74
05N/01E-13N01	0	20	2.7	34	54	2	0.6	164
05N/01E-15E01	0	6.4	2.1	7.2	37	0.7	1.5	45
05N/01E-17E01	0	34	8.2	24	30	1	1.7	201
05N/01E-25N01D1	0	6.6	2.6	5.6	29	0.5	1.8	48
05N/01E-29H01	0	8.4	3.4	11	38	0.8	2.7	63
05N/01E-34G04	0	12	5.0	9.4	28	0.6	2.0	76
05N/02E-08B01	0	14	1.2	16	47	1	0.1	87
05N/02E-15K01	0	10	3.6	6.1	25	0.4	0.8	59
05N/02E-21R01	0	2.5	0.17	40	92	7	0.3	51
05N/03E-12P01	0	9.9	2.4	4.7	23	0.4	0.4	46
05N/03E-16P01	0	8.8	1.6	5.6	30	0.5	0.2	40

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Carbonate field (mg/L as CO_3)	Alkalinity, field (mg/L - $CaCO_3$)	Alkalinity lab (mg/L as $CaCO_3$)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
03N/01E-35B02	0	90	89	11	4.0	3.4	0.2	50
03N/02E-01C02	11	58	57	0.0	1.4	1.6	0.2	15
03N/02E-03B01	0	110	108	13	1.8	3.0	0.2	51
03N/02E-05E02	0	62	65	15	1.3	1.7	0.2	61
	0	62	65	15	1.2	1.6	0.3	61
03N/02E-10R01	0	136	131	13	1.7	5.0	0.3	45
03N/02E-20H01	0	85	93	8.3	1.2	1.3	0.2	53
03N/02E-23H01	0	133	134	16	1.6	1.6	0.3	54
03N/02E-35D02	0	89	89	11	0.9	1.5	0.2	60
03N/03E-03P01	0	56	54	17	0.6	1.4	0.1	50
03N/03E-34R01	0	91	89	1.1	1.1	2.6	0.1	40
04N/01E-07H01	0	123	121	38	1.6	4.3	0.3	67
	0	122	121	38	1.6	4.2	0.3	68
04N/01E-10E01	0	91	90	8.8	3.1	4.5	0.3	36
04N/01E-13B01	0	96	94	23	2.2	33	0.3	43
04N/01E-18J01	6	144	142	0.8	13	23	0.5	35
04N/01E-19F02	0	117	115	18	1.0	2.5	0.2	63
04N/01E-25L01	0	90	89	35	0.9	1.6	0.3	62
	0	89	88	35	0.8	1.6	0.3	62
04N/01E-33B02	0	122	123	30	0.6	2.2	0.4	62
04N/02E-02A02	0	99	98	2.4	0.8	1.5	0.3	32
04N/02E-06K01	0	34	33	13	<0.2	1.4	0.2	54
04N/02E-10N01	0	49	51	30	<0.2	1.9	0.1	51
04N/02E-23B02	0	20	20	2.4	2.9	1.7	0.2	18
04N/02E-29A02	0	35	33	4.3	5.2	1.7	0.2	29
04N/03E-02D02	0	52	41	10	<0.2	2.5	0.1	26
04N/03E-28R02	0	67	67	0.7	1.3	2.3	0.2	25
04N/03E-29L01	0	157	151	7.7	2.1	2.4	0.2	33
05N/01E-10F01	0	61	46	19	29	6.4	0.3	58
05N/01E-13N01	0	134	135	4.1	1.5	1.5	0.1	31
05N/01E-15E01	0	37	38	36	1.8	1.9	0.2	49
05N/01E-17E01	0	165	160	8.0	3.5	5.7	0.5	28
05N/01E-25N01D1	0	39	39	15	0.8	4.5	0.1	31
05N/01E-29H01	0	52	51	32	3.0	5.2	0.3	56
05N/01E-34G04	0	62	63	24	1.3	4.1	0.2	65
05N/02E-08B01	0	71	63	5.5	1.2	3.6	0.1	39
05N/02E-15K01	0	48	48	19	0.5	1.5	0.3	39
05N/02E-21R01	22	78	81	0.0	<0.2	4.3	2.0	23
05N/03E-12P01	0	38	40	18	0.6	6.9	0.2	26
05N/03E-16P01	0	33	31	32	1.1	4.3	0.2	25

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Solids, residue at 180 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO2+NO3 dissolved (mg/L as N)	Phosphorous dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Radon 222 total (pCi/L)
03N/01E-35B02	149	155	1.2	0.15	<10	<3	<1	510
03N/02E-01C02	71	92	<0.10	0.01	<10	4	<1	110
03N/02E-03B01	157	170	1.0	0.08	<10	4	1	380
03N/02E-05E02	124	128	0.14	0.07	<10	8	2	470
	118	129	0.15	0.07	<10	8	2	280
03N/02E-10R01	173	187	0.16	0.22	<10	3	100	350
03N/02E-20H01	132	141	<0.10	0.10	<10	160	10	<80
03N/02E-23H01	173	189	<0.10	0.12	<10	200	290	130
03N/02E-35D02	142	151	<0.10	0.16	<10	<3	<1	150
03N/03E-03P01	102	109	0.34	0.04	<10	<3	1	220
03N/03E-34R01	131	136	<0.10	0.03	<10	<3	<1	<80
04N/01E-07H01	183	196	0.16	0.09	<10	6	<1	300
	183	196	0.16	0.09	<10	6	<1	310
04N/01E-10E01	131	136	<0.10	0.03	<10	270	440	450
04N/01E-13B01	191	191	0.10	0.05	<10	37	<1	430
04N/01E-18J01	228	251	<0.10	0.05	<10	60	41	590
04N/01E-19F02	166	182	0.16	0.18	<10	9	<1	160
04N/01E-25L01	142	153	<0.10	0.16	<10	47	2	420
	146	152	<0.10	0.16	<10	48	2	440
04N/01E-33B02	176	184	0.12	0.15	<10	38	120	430
04N/02E-02A02	130	135	<0.10	0.16	<10	35	45	<80
04N/02E-06K01	88	90	0.10	0.07	<10	<3	<1	820
04N/02E-10N01	97	104	0.20	0.07	10	5	1	410
04N/02E-23B02	43	46	0.29	0.02	<10	<3	3	310
04N/02E-29A02	67	73	<0.10	<0.01	<10	260	620	460
04N/03E-02D02	75	75	1.8	0.04	<10	<3	<1	360
04N/03E-28R02	95	103	0.25	0.03	<10	<3	<1	<80
04N/03E-29L01	181	196	<0.10	0.02	<10	730	260	310
05N/01E-10F01	118	158	<0.10	0.11	<10	7,700	210	<80
05N/01E-13N01	166	172	<0.10	0.03	<10	4	31	190
05N/01E-15E01	84	92	<0.10	0.13	<10	9	2	640
05N/01E-17E01	192	205	<0.10	0.05	<10	68	690	720
05N/01E-25N01D1	86	77	<0.10	0.06	<10	33	20	190
05N/01E-29H01	114	121	<0.10	0.21	10	53	19	800
05N/01E-34G04	132	139	0.48	0.15	<10	7	5	350
05N/02E-08B01	109	122	0.92	0.09	<10	3	<1	290
05N/02E-15K01	88	96	1.1	0.01	<10	<3	<1	490
05N/02E-21R01	121	119	<0.10	0.01	<10	3	2	320
05N/03E-12P01	66	77	0.68	0.09	<10	3	<1	390
05N/03E-16P01	65	71	0.93	0.18	<10	<3	<1	350

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Date	Temperature water (deg C)	Specific conductance (µS/cm)	Specific conductance lab (µS/cm)	pH (standard units)	pH lab (standard units)	Oxygen, dissolved (mg/L)	Turbidity (NTU)	Hardness total (mg/L as $CaCO_3$)
05N/03E-27N02	05-24-88	11.0	118	120	8.2	8.1	6.8	0.1	42
06N/03E-34H02	05-24-88	11.0	102	105	8.4	7.9	4.3	0.2	33
Deionized water blank	04-29-88	--	--	2	--	7.4	--	--	--
	05-11-88	--	--	2	--	5.6	--	0.1	--
	05-11-88	--	--	2	--	6.1	--	--	--
	05-17-88	--	--	3	--	6.4	--	0.2	--
	05-18-88	--	--	1	--	6.2	--	0.1	--

Local well number	Hardness noncarbonate total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium percent	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate field (mg/L as HCO_3)
05N/03E-27N02	0	15	1.1	9.9	34	0.7	0.2	78
06N/03E-34H02	0	12	0.78	8.9	37	0.7	0.1	57
Deionized water blank	--	<0.02	<0.01	<0.2	--	--	0.1	--
	--	0.06	0.01	<0.2	--	--	0.1	--
	--	<0.02	<0.01	<0.2	--	--	0.1	--
	--	<0.02	<0.01	<0.2	--	--	0.1	--
	--	<0.02	<0.01	<0.2	--	--	0.1	--

Table A2.--Values and concentrations of common constituents and radon--Continued

Local well number	Carbonate field (mg/L as CO_3)	Alkalinity, field (mg/L - $CaCO_3$)	Alkalinity lab (mg/L as $CaCO_3$)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
05N/03E-27N02	0	64	61	0.8	0.6	1.3	0.2	31
06N/03E-34H02	1	49	49	0.4	1.2	1.5	0.2	20
Deionized water blank	--	--	1.0	--	<0.2	0.4	0.1	0.02
	--	--	1.0	--	<0.2	0.2	0.2	<0.01
	--	--	1.0	--	<0.2	0.1	0.2	<0.01
	--	--	2.0	--	<0.2	0.2	0.2	0.02
	--	--	1.0	--	<0.2	0.2	0.1	0.01

Local well number	Solids, residue at 180 deg. C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO2+NO3, dissolved (mg/L as N)	Phosphorous, dissolved (mg/L as P)	Aluminum, dissolved (µg/L as Al)	Iron, dissolved (µg/L as Fe)	Manganese, dissolved (µg/L as Mn)	Radon 222 total (pCi/L)
05N/03E-27N02	90	98	<0.10	0.06	<10	<3	<1	380
06N/03E-34H02	75	77	0.59	0.03	<10	16	2	130
Deionized water blank	<1	--	<0.10	0.03	<10	<3	<1	<80
	1	--	<0.10	<0.01	<10	<3	<1	<80
	<1	--	<0.10	<0.01	<10	<3	<1	<80
	<1	--	<0.10	0.02	<10	<3	<1	<80
	<1	--	<0.10	0.02	<10	<3	1	<80

Table A3.--Concentrations of trace elements and cyanide

[μg/L, micrograms per liter; mg/L milligrams per liter]

Local well number	Date	Antimony, dissolved (μg/L as Sb)	Arsenic, dissolved (μg/L as As)	Barium, dissolved (μg/L as Ba)	Beryllium, dissolved (μg/L as Be)	Boron, dissolved (μg/L as B)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Copper, dissolved (μg/L as Cu)	Lead, dissolved (μg/L as Pb)
01N/03E-12L04	04-27-88	<1	<1	3	<0.5	<10	<1	<1	18	<5
01N/04E-08K05	04-27-88	<1	<1	<2	<0.5	<10	<1	<1	2	<5
02N/01E-15Q01	05-03-88	<1	4	10	<0.5	10	<1	<1	3	<5
02N/01E-23Q03	04-28-88	<1	1	8	<0.5	10	<1	<1	2	<5
02N/01E-36B09	04-28-88	<1	1	5	<0.5	20	<1	<1	2	<5
02N/02E-07A02	04-27-88	<1	<1	21	<0.5	30	<1	<1	2	<5
	04-27-88	<1	<1	21	<0.5	30	<1	<1	1	<5
02N/02E-27D02	04-28-88	<1	<1	2	<0.5	<10	<1	<1	2	<5
02N/03E-06M01	04-26-88	<1	1	<2	<0.5	<10	<1	<1	1	<5
03N/01E-17P01	04-30-88	<1	2	10	<0.5	<10	<1	<1	4	<5
	04-30-88	<1	2	10	<0.5	<10	<1	<1	<1	<5
03N/01E-35B02	04-26-88	<1	<1	5	<0.5	10	<1	<1	2	<5
03N/02E-03B01	04-25-88	13	<1	4	<0.5	<10	<1	<1	<1	<5
03N/02E-20H01	04-28-88	<1	2	11	<0.5	<10	<1	<1	2	<5
03N/02E-35D02	04-26-88	<1	1	9	<0.5	<10	<1	<1	<1	<5
	07-19-88	--	--	--	--	--	--	--	--	--
03N/03E-03P01	04-26-88	<1	<1	<2	<0.5	<10	<1	<1	<1	<5
	07-19-88	--	--	--	--	--	--	--	--	--
04N/01E-19F02	04-29-88	1	1	30	<0.5	<10	<1	3	1	<5
04N/01E-33B02	04-30-88	<1	1	8	<0.5	<10	<1	<1	1	<5
04N/02E-10N01	04-25-88	<1	<1	8	<0.5	<10	<1	<1	2	<5
04N/03E-02D02	04-25-88	<1	<1	<2	<0.5	<10	<1	<1	1	<5
05N/01E-34G04	04-29-88	<1	1	18	<0.5	<10	<1	2	2	<5
05N/02E-08B01	05-03-88	<1	1	<2	<0.5	40	<1	<1	1	<5
Deionized water blank	04-29-88	<1	<1	<2	<0.5	<10	<1	<1	1	<5

Table A3.--Concentrations of trace elements and cyanide--Continued

Local well number	Mercury, dissolved (μg/L as Hg)	Molybdenum, dissolved (μg/L as Mo)	Nickel, dissolved (μg/L as Ni)	Selenium, dissolved (μg/L as Se)	Silver, dissolved (μg/L as Ag)	Thallium, dissolved (μg/L as Tl)	Vanadium, dissolved (μg/L as V)	Zinc, dissolved (μg/L as Zn)	Cyanide, dissolved (mg/L as CN)
01N/03E-12L04	<0.1	<1	3	<1	<1	<1	2	4	<0.01
01N/04E-08K05	<0.1	<1	2	1	<1	<1	2	34	<0.01
02N/01E-15Q01	<0.1	1	4	<1	<1	<1	10	5	<0.01
02N/01E-23Q03	<0.1	<1	<1	<1	<1	<1	11	12	<0.01
02N/01E-36B09	<0.1	<1	<1	<1	<1	<1	9	<3	<0.01
02N/02E-07A02	<0.1	<1	1	<1	<1	<1	4	<3	<0.01
	<0.1	<1	1	<1	<1	<1	4	<3	<0.01
02N/02E-27D02	<0.1	<1	3	<1	1	<1	15	<3	<0.01
02N/03E-06M01	<0.1	<1	3	<1	<1	<1	23	<3	<0.01
03N/01E-17P01	<0.1	1	<1	<1	<1	<1	11	180	<0.01
	<0.1	1	<1	<1	<1	<1	11	160	<0.01
03N/01E-35B02	<0.1	<1	1	<1	<1	<1	13	<3	<0.01
03N/02E-03B01	<0.1	<1	<1	<1	<1	<1	10	19	<0.01
03N/02E-20H01	<0.1	1	<1	<1	<1	<1	14	69	<0.01
03N/02E-35D02	<0.1	<1	<1	<1	<1	<1	19	<3	--
	--	--	--	--	--	--	--	--	<0.01
03N/03E-03P01	<0.1	3	<1	<1	<1	--	8	57	<0.01
	--	--	--	--	--	<1	--	--	<0.01
04N/01E-19F02	<0.1	<1	<1	<1	<1	<1	11	17	<0.01
04N/01E-33B02	<0.1	<1	2	<1	<1	<1	16	32	<0.01
04N/02E-10N01	<0.1	<1	<1	<1	<1	<1	5	7	<0.01
04N/03E-02D02	<0.1	<1	2	<1	<1	<1	2	36	<0.01
05N/01E-34G04	<0.1	<1	<1	<1	<1	<1	7	6	<0.01
05N/02E-08B01	<0.1	1	2	<1	1	<1	4	97	<0.01
Deionized water blank	<0.1	<1	<1	<1	<1	<1	<1	<3	<0.01

Table A.4--Concentrations of radiochemical constituents

[μg/L, micrograms per liter; pCi/L, picocuries per liter; U, uranium; U-nat, natural uranium; Th-230, Thorium-230; Cs-137, Cesium-137; Yt-90, Yttrium-90; Ra-228, Radium-228]

Local well number	Date	Gross alpha, dissolved (μg/L as U-nat)	Gross alpha, dissolved (pCi/L as Th-230)	Gross beta, dissolved (pCi/L as Cs-137)	Gross beta, dissolved (pCi/L as Sr/Yt-90)	Radium 226, dissolved, radon method (pCi/L)	Radium 228, dissolved (pCi/L as Ra-228)	Uranium natural, dissolved (μg/L as U)
01N/03E-12L04	04-27-88	<0.4	<0.4	1.7	1.5	0.03	<1.0	<1.0
01N/04E-08K05	04-27-88	<0.4	<0.4	0.4	0.4	<0.02	<1.0	<1.0
02N/01E-15Q01	05-03-88	0.4	<0.4	4.5	3.4	0.03	<1.0	<1.0
02N/01E-23Q03	04-28-88	<0.4	<0.4	3.5	2.7	0.03	<1.0	<1.0
02N/01E-36B09	04-28-88	0.7	0.7	4.7	3.8	0.03	<1.0	<1.0
02N/02E-07A02	04-27-88	<0.4	<0.4	3.1	2.3	<0.02	<1.0	<1.0
	04-27-88	0.9	0.6	3.9	2.9	<0.02	<1.0	<1.0
02N/02E-27D02	04-28-88	<0.4	<0.4	2.3	1.9	<0.02	<1.0	<1.0
02N/03E-06M01	04-26-88	<0.4	<0.4	2.3	1.8	<0.02	<1.0	<1.0
03N/01E-17P01	04-30-88	1.2	1.3	3.6	2.6	0.03	<1.0	1.1
	04-30-88	1.8	1.8	4.6	3.3	0.03	<1.0	1.2
03N/01E-35B02	04-26-88	0.6	0.5	2.3	1.7	<0.02	<1.0	<1.0
03N/02E-03B01	04-25-88	0.4	<0.4	2.0	1.5	<0.02	<1.0	<1.0
03N/02E-20H01	04-28-88	0.9	0.7	2.2	1.8	<0.02	<1.0	<1.0
03N/02E-35D02	04-26-88	0.6	0.5	2.7	2.1	0.04	<1.0	<1.0
03N/03E-03P01	04-26-88	<0.4	<0.4	0.4	<0.4	0.02	<1.0	<1.0
04N/01E-19F02	04-29-88	0.5	<0.4	2.2	1.6	0.02	<1.0	<1.0
04N/01E-33B02	04-30-88	1.0	0.6	2.3	1.8	0.03	<1.0	<1.0
04N/02E-10N01	04-25-88	<0.4	<0.4	2.9	2.2	<0.02	<1.0	<1.0
04N/03E-02D02	04-25-88	<0.4	<0.4	0.6	0.5	<0.02	<1.0	<1.0
05N/01E-34G04	04-29-88	0.5	<0.4	2.4	1.8	<0.02	<1.0	<1.0
05N/02E-08B01	05-03-88	<0.4	<0.4	0.5	0.4	0.03	1.4	<1.0
Deionized water blank	04-29-88	<0.4	<0.4	<0.4	<0.4	<0.02	<1.0	<1.0

Table A5.--Concentrations of organic compounds

[μg/L, micrograms per liter; mg/L, milligrams per liter; α, alpha; β, beta; δ, delta]

		Volatile organic compounds							
Local well number	Date	Chloro-methane total (μg/L)	Di-chloro-methane total (μg/L)	Tri-chloro-methane total (μg/L)	Tetra-chloro-methane total (μg/L)	Bromo-methane total (μg/L)	Di-bromo-methane total (μg/L)	Tri-bromo-methane total (μg/L)	Bromo-di-chloro-methane total (μg/L)
01N/03E-12L04	04-27-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	04-27-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	05-03-88	<0.2	<0.2	4.8	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-23Q03	04-28-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-36B09	04-28-88	--	--	--	--	--	--	--	--
	07-20-88	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-07A02	04-27-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	04-27-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-27D02	04-28-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	04-26-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	04-30-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	04-30-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-35B02	04-26-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	04-25-88	--	--	--	--	--	--	--	--
	07-19-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-20H01	04-28-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	04-26-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	04-26-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	04-29-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-33B02	04-30-88	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2
04N/02E-10N01	04-25-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	04-25-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	04-29-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	05-03-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Deionized water blank	04-26-88	--	--	--	--	--	--	--	--
	04-29-88	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	05-03-88	<0.2	1.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

Volatile organic compounds--Continued

Local well number	Dibromochloromethane total (µg/L)	Trichlorofluoromethane total (µg/L)	Dichlorodifluoromethane total (µg/L)	Chloroethane total (µg/L)	1,1-Dichloroethane total (µg/L)	1,2-Dichloroethane total (µg/L)	1,1,1-Trichloroethane total (µg/L)	1,1,2-Trichloroethane total (µg/L)	1,1,1,2-Tetrachloroethane total (µg/L)
01N/03E-12L04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	6.8	<0.2	<0.2
02N/01E-23Q03	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
02N/01E-36B09	--	--	--	--	--	--	--	--	--
	<0.2	1.3	<0.2	<0.2	<0.2	<0.2	0.7	<0.2	<0.2
02N/02E-07A02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2
02N/02E-27D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-35B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	--	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-20H01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-33B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/02E-10N01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Deionized water blank	--	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

Volatile organic compounds--Continued

Local well number	1,1,2,2-Tetrachloroethane total (µg/L)	1,2-Dibromoethane total (µg/L)	Vinyl chloride total (µg/L)	1,1-Dichloroethene total (µg/L)	cis 1,2-Dichloroethene total (µg/L)	trans 1,2-Dichloroethene total (µg/L)	Trichloroethene total (µg/L)	Tetrachloroethene total (µg/L)	1,2-Dichloropropane total (µg/L)
01N/03E-12L04	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	<0.2	<0.025	<0.2	0.9	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-23Q03	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2
02N/01E-36B09	--	<0.025	--	--	--	--	--	--	--
	<0.2	--	<0.2	<0.2	<0.2	<0.2	<0.2	14	<0.2
02N/02E-07A02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	0.2	1.4	<0.2
	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	0.2	0.7	<0.2
02N/02E-27D02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	1.3	<0.2
03N/01E-35B02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	--	<0.025	--	--	--	--	--	--	--
	<0.2	--	<0.2	<0.2	<0.2	<0.2	<0.2	0.6	<0.2
03N/02E-20H01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-33B02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/02E-10N01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Deionized water blank	--	<0.025	--	--	--	--	--	--	--
	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2
	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

Local well number	Volatile organic compounds--Continued 1,3-Dichloropropane total (µg/L)	2,2-Dichloropropane total (µg/L)	1,2,3-Trichloropropane total (µg/L)	1,2-Dibromo-3-chloropropane total (µg/L)	1,1-Dichloropropene total (µg/L)	1,3-Dichloropropene total (µg/L)	cis 1,3-Dichloropropene total (µg/L)	trans 1,3-Dichloropropene total (µg/L)
01N/03E-12L04	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
02N/01E-23Q03	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
02N/01E-36B09	--	--	--	<0.025	--	--	--	--
	<0.2	<0.2	<0.2	--	<0.2	<0.2	<0.2	<0.2
02N/02E-07A02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
02N/02E-27D02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
03N/01E-35B02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	--	--	--	<0.025	--	--	--	--
	<0.2	<0.2	<0.2	--	<0.2	<0.2	<0.2	<0.2
03N/02E-20H01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
04N/01E-33B02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
04N/02E-10N01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
Deionized water blank	--	--	--	<0.025	--	--	--	--
	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.025	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

Local well number	Benzene total (µg/L)	Chloro-benzene total (µg/L)	1,2-Di-chloro-benzene total (µg/L)	1,3-Di-chloro-benzene total (µg/L)	1,4-Di-chloro-benzene total (µg/L)	Bromo-benzene total (µg/L)	Toluene total (µg/L)	2-Chloro-toluene total (µg/L)
	Volatile organic compounds--Continued							
01N/03E-12L04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-23Q03	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-36B09	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-07A02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-27D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-35B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-20H01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.5	<0.2
04N/01E-33B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/02E-10N01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Deionized water blank	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

Volatile organic compounds--Continued

Local well number	4-Chloro-toluene total (µg/L)	Di-methyl-benzene total (µg/L)	1,2-Di-methyl-benzene total (µg/L)	1,3-Di-methyl-benzene total (µg/L)	1,4-Di-methyl-benzene total (µg/L)	Ethyl-benzene total (µg/L)	Ethenyl-benzene total (µg/L)	2-Chloro-ethyl vinyl ether total (µg/L)
01N/03E-12L04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
01N/04E-08K05	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-15Q01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-23Q03	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/01E-36B09	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-07A02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/02E-27D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
02N/03E-06M01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-17P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/01E-35B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-03B01	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-20H01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/02E-35D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
03N/03E-03P01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-19F02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/01E-33B02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/02E-10N01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
04N/03E-02D02	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/01E-34G04	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
05N/02E-08B01	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Deionized water blank	--	--	--	--	--	--	--	--
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Table A5.--Concentrations of organic compounds--Continued

		Acid and base-neutral extractable compounds and detergents							
Local well number	Date	Phenol total (µg/L)	2,4-Dimethylphenol total (µg/L)	2-Chlorophenol total (µg/L)	2,4-Dichlorophenol total (µg/L)	2,4,6-Trichlorophenol total (µg/L)	Pentachlorophenol total (µg/L)	4-Chloro-3-methylphenol total (µg/L)	2-Nitrophenol total (µg/L)
01N/03E-12L04	04-27-88	<5	<5	<5	<5	<20	<30	<30	<5
01N/04E-08K05	04-27-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/01E-15Q01	05-03-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/01E-23Q03	04-28-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/01E-36B09	04-28-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/02E-07A02	04-27-88	<5	<5	<5	<5	<20	<30	<30	<5
	04-27-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/02E-27D02	04-28-88	<5	<5	<5	<5	<20	<30	<30	<5
02N/03E-06M01	04-26-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/01E-17P01	04-30-88	<5	<5	<5	<5	<20	<30	<30	<5
	04-30-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/01E-35B02	04-26-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/02E-03B01	04-25-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/02E-20H01	04-28-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/02E-35D02	04-26-88	<5	<5	<5	<5	<20	<30	<30	<5
03N/03E-03P01	04-26-88	<5	<5	<5	<5	<20	<30	<30	<5
04N/01E-19F02	04-29-88	<5	<5	<5	<5	<20	<30	<30	<5
04N/01E-33B02	04-30-88	<5	<5	<5	<5	<20	<30	<30	<5
04N/02E-10N01	04-25-88	<5	<5	<5	<5	<20	<30	<30	<5
04N/03E-02D02	04-25-88	<5	<5	<5	<5	<20	<30	<30	<5
05N/01E-34G04	04-29-88	<5	<5	<5	<5	<20	<30	<30	<5
05N/02E-08B01	05-03-88	<5	<5	<5	<5	<20	<30	<30	<5
Deionized water blank	04-26-88	<5	<5	<5	<5	<20	<30	<30	<5
	04-29-88	<5	<5	<5	<5	<20	<30	<30	<5

Table A5.--Concentrations of organic compounds--Continued

Acid and base-neutral extractable compounds and detergents--Continued

Local well number	4-Nitrophenol total (µg/L)	2,4,-Dinitrophenol total (µg/L)	4,6-Dinitro-2-methylphenol total (µg/L)	bis (2-Chloroethoxy) methane total (µg/L)	Hexachloroethane total (µg/L)	Hexachlorobutadiene total (µg/L)	Hexachlorocyclopentadiene total (µg/L)	bis (2-Chloroethyl) ether total (µg/L)	bis (2-Chloroisopropyl) ether total (µg/L)
01N/03E-12L04	<30	<20	<30	<5	<5	<5	<5	<5	<5
01N/04E-08K05	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/01E-15Q01	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/01E-23Q03	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/01E-36B09	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/02E-07A02	<30	<20	<30	<5	<5	<5	<5	<5	<5
	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/02E-27D02	<30	<20	<30	<5	<5	<5	<5	<5	<5
02N/03E-06M01	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/01E-17P01	<30	<20	<30	<5	<5	<5	<5	<5	<5
	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/01E-35B02	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/02E-03B01	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/02E-20H01	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/02E-35D02	<30	<20	<30	<5	<5	<5	<5	<5	<5
03N/03E-03P01	<30	<20	<30	<5	<5	<5	<5	<5	<5
04N/01E-19F02	<30	<20	<30	<5	<5	<5	<5	<5	<5
04N/01E-33B02	<30	<20	<30	<5	<5	<5	<5	<5	<5
04N/02E-10N01	<30	<20	<30	<5	<5	<5	<5	<5	<5
04N/03E-02D02	<30	<20	<30	<5	<5	<5	<5	<5	<5
05N/01E-34G04	<30	<20	<30	<5	<5	<5	<5	<5	<5
05N/02E-08B01	<30	<20	<30	<5	<5	<5	<5	<5	<5
Deionized water	<30	<20	<30	<5	<5	<5	<5	<5	<5
blank	<30	<20	<30	<5	<5	<5	<5	<5	<5

Table A5.--Concentrations of organic compounds--Continued

Acid and base-neutral extractable compounds and detergents--Continued

Local well number	4-Chlorophenyl phenyl ether total (µg/L)	4-Bromophenyl phenyl ether total (µg/L)	1,2,4-Trichlorobenzene total (µg/L)	Hexachlorobenzene total (µg/L)	Nitrobenzene total (µg/L)	2,4-Dinitrotoluene total (µg/L)	2,6-Dinitrotoluene total (µg/L)	Isophorone total (µg/L)	Dimethyl phthalate total (µg/L)
01N/03E-12L04	<5	<5	<5	<5	<5	<5	<5	<5	<5
01N/04E-08K05	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/01E-15Q01	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/01E-23Q03	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/01E-36B09	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/02E-07A02	<5	<5	<5	<5	<5	<5	<5	<5	<5
	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/02E-27D02	<5	<5	<5	<5	<5	<5	<5	<5	<5
02N/03E-06M01	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/01E-17P01	<5	<5	<5	<5	<5	<5	<5	<5	<5
	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/01E-35B02	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/02E-03B01	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/02E-20H01	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/02E-35D02	<5	<5	<5	<5	<5	<5	<5	<5	<5
03N/03E-03P01	<5	<5	<5	<5	<5	<5	<5	<5	<5
04N/01E-19F02	<5	<5	<5	<5	<5	<5	<5	<5	<5
04N/01E-33B02	<5	<5	<5	<5	<5	<5	<5	<5	<5
04N/02E-10N01	<5	<5	<5	<5	<5	<5	<5	<5	<5
04N/03E-02D02	<5	<5	<5	<5	<5	<5	<5	<5	<5
05N/01E-34G04	<5	<5	<5	<5	<5	<5	<5	<5	<5
05N/02E-08B01	<5	<5	<5	<5	<5	<5	<5	<5	<5
Deionized water	<5	<5	<5	<5	<5	<5	<5	<5	<5
blank	<5	<5	<5	<5	<5	<5	<5	<5	<5

Table A5.--Concentrations of organic compounds--Continued

Acid and base-neutral extractable compounds and detergents--Continued

Local well number	Diethyl phthalate total (µg/L)	Di-n-butyl phthalate total (µg/L)	n-Butyl benzyl phthalate total (µg/L)	Di-n-octyl phthalate total (µg/L)	bis(2-ethyl hexyl) phthalate total (µg/L)	Naphthalene total (µg/L)	2-Chloronaphthalene total (µg/L)	Naphthalenes, polychlor. total (µg/L)	Acenaphthylene total (µg/L)
01N/03E-12L04	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
01N/04E-08K05	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
02N/01E-15Q01	<5	<5	<5	<10	10	<5	<5	<0.1	<5
02N/01E-23Q03	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
02N/01E-36B09	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
02N/02E-07A02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
02N/02E-27D02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
02N/03E-06M01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
03N/01E-17P01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
03N/01E-35B02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
03N/02E-03B01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
03N/02E-20H01	<5	<5	<5	<10	8	<5	<5	<0.1	<5
03N/02E-35D02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
03N/03E-03P01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
04N/01E-19F02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
04N/01E-33B02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
04N/02E-10N01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
04N/03E-02D02	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
05N/01E-34G04	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
05N/02E-08B01	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
Deionized water	<5	<5	<5	<10	<5	<5	<5	<0.1	<5
blank	<5	<5	<5	<10	15	<5	<5	<0.1	<5

Table A5.--Concentrations of organic compounds--Continued

Acid and base-neutral extractable compounds and detergents--Continued

Local well number	Ace-naphth-ene total (µg/L)	Fluor-ene total (µg/L)	Anthra-cene-total (µg/L)	Benzo (a) anthra-cene-total (µg/L)	Di-benzo (a,h) anthra-cene-total (µg/L)	Phenan-threne total (µg/L)	Fluor-anthene total (µg/L)	Benzo (b) fluor-anthene total (µg/L)	Benzo (k) fluor-anthene total (µg/L)
01N/03E-12L04	<5	<5	<5	<5	<10	<5	<5	<10	<10
01N/04E-08K05	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/01E-15Q01	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/01E-23Q03	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/01E-36B09	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/02E-07A02	<5	<5	<5	<5	<10	<5	<5	<10	<10
	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/02E-27D02	<5	<5	<5	<5	<10	<5	<5	<10	<10
02N/03E-06M01	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/01E-17P01	<5	<5	<5	<5	<10	<5	<5	<10	<10
	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/01E-35B02	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/02E-03B01	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/02E-20H01	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/02E-35D02	<5	<5	<5	<5	<10	<5	<5	<10	<10
03N/03E-03P01	<5	<5	<5	<5	<10	<5	<5	<10	<10
04N/01E-19F02	<5	<5	<5	<5	<10	<5	<5	<10	<10
04N/01E-33B02	<5	<5	<5	<5	<10	<5	<5	<10	<10
04N/02E-10N01	<5	<5	<5	<5	<10	<5	<5	<10	<10
04N/03E-02D02	<5	<5	<5	<5	<10	<5	<5	<10	<10
05N/01E-34G04	<5	<5	<5	<5	<10	<5	<5	<10	<10
05N/02E-08B01	<5	<5	<5	<5	<10	<5	<5	<10	<10
Deionized water	<5	<5	<5	<5	<10	<5	<5	<10	<10
blank	<5	<5	<5	<5	<10	<5	<5	<10	<10

Table A5.--Concentrations of organic compounds--Continued

Acid and base-neutral extractable compounds and detergents--Continued

Local well number	Pyrene total (µg/L)	Benzo-(a) pyrene total (µg/L)	Indeno (1,2,3-cd) pyrene total (µg/L)	Chrysene total (µg/L)	Benzo (g,h,i) perylene total (µg/L)	n-nitrosodimethylamine total (µg/L)	n-nitrosodi-n-propylamine total (µg/L)	n-nitrosodiphenylamine total (µg/L)	Methylene blue active substance (µg/L)
01N/03E-12L04	<5	<10	<10	<10	<10	<5	<5	<5	0.01
01N/04E-08K05	<5	<10	<10	<10	<10	<5	<5	<5	0.01
02N/01E-15Q01	<5	<10	<10	<10	<10	<5	<5	<5	0.06
02N/01E-23Q03	<5	<10	<10	<10	<10	<5	<5	<5	0.03
02N/01E-36B09	<5	<10	<10	<10	<10	<5	<5	<5	0.04
02N/02E-07A02	<5	<10	<10	<10	<10	<5	<5	<5	0.02
	<5	<10	<10	<10	<10	<5	<5	<5	0.04
02N/02E-27D02	<5	<10	<10	<10	<10	<5	<5	<5	0.02
02N/03E-06M01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
03N/01E-17P01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
	<5	<10	<10	<10	<10	<5	<5	<5	0.01
03N/01E-35B02	<5	<10	<10	<10	<10	<5	<5	<5	0.02
03N/02E-03B01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
03N/02E-20H01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
03N/02E-35D02	<5	<10	<10	<10	<10	<5	<5	<5	<0.01
03N/03E-03P01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
04N/01E-19F02	<5	<10	<10	<10	<10	<5	<5	<5	0.01
04N/01E-33B02	<5	<10	<10	<10	<10	<5	<5	<5	0.01
04N/02E-10N01	<5	<10	<10	<10	<10	<5	<5	<5	0.01
04N/03E-02D02	<5	<10	<10	<10	<10	<5	<5	<5	0.02
05N/01E-34G04	<5	<10	<10	<10	<10	<5	<5	<5	0.01
05N/02E-08B01	<5	<10	<10	<10	<10	<5	<5	<5	0.03
Deionized water blank	<5	<10	<10	<10	<10	<5	<5	<5	0.01
	<5	<10	<10	<10	<10	<5	<5	<5	0.01

Table A.5--Concentrations of organic compounds--Continued

		Pesticides and polychlorinated biphenyls							
Local well number	Date	Aldrin total (µg/L)	Chlordane total (µg/L)	DDD total (µg/L)	DDE total (µg/L)	DDT total (µg/L)	Dieldrin total (µg/L)	Endosulfan total (µg/L)	Endrin total (µg/L)
01N/03E-12L04	04-27-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
01N/04E-08K05	04-27-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/01E-15Q01	05-03-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/01E-23Q03	04-28-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/01E-36B09	04-28-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/02E-07A02	04-27-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	04-27-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/02E-27D02	04-28-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
02N/03E-06M01	04-26-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/01E-17P01	04-30-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	04-30-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/01E-35B02	04-26-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/02E-03B01	04-25-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/02E-20H01	04-28-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/02E-35D02	04-26-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
03N/03E-03P01	04-26-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
04N/01E-19F02	04-29-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
04N/01E-33B02	04-30-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
04N/02E-10N01	04-25-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
04N/03E-02D02	04-25-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
05N/01E-34G04	04-29-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
05N/02E-08B01	05-03-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deionized water blank	04-26-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	04-29-88	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table A5.--Concentrations of organic compounds--Continued

Pesticides and polychlorinated biphenyls--Continued

Local well number	Heptachlor total (µg/L)	Heptachlor epoxide total (µg/L)	α-Hexachlorobenzene total (µg/L)	β-Hexachlorobenzene total (µg/L)	δ-Hexachlorobenzene total (µg/L)	Lindane total (µg/L)	Methoxychlor total (µg/L)	Mirex total (µg/L)	Perthane total (µg/L)
01N/03E-12L04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
01N/04E-08K05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/01E-15Q01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/01E-23Q03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/01E-36B09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/02E-07A02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/02E-27D02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
02N/03E-06M01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/01E-17P01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/01E-35B02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/02E-03B01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/02E-20H01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/02E-35D02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
03N/03E-03P01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
04N/01E-19F02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
04N/01E-33B02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
04N/02E-10N01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
04N/03E-02D02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
05N/01E-34G04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
05N/02E-08B01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
Deionized water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1
blank	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1

Table A5.--Concentrations of organic compounds--Continued

	Pesticides and polychlorinated biphenyls--Continued								
Local well number	Tox-aphene total (μg/L)	PCB total (μg/L)	Aroclor 1016 PCB total (μg/L)	Aroclor 1221 PCB total (μg/L)	Aroclor 1232 PCB total (μg/L)	Aroclor 1242 PCB total (μg/L)	Aroclor 1248 PCB total (μg/L)	Aroclor 1254 PCB total (μg/L)	Aroclor 1260 PCB total (μg/L)
01N/03E-12L04	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
01N/04E-08K05	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/01E-15Q01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/01E-23Q03	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/01E-36B09	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/02E-07A02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/02E-27D02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
02N/03E-06M01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/01E-17P01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/01E-35B02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/02E-03B01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/02E-20H01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/02E-35D02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03N/03E-03P01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04N/01E-19F02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04N/01E-33B02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04N/02E-10N01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
04N/03E-02D02	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
05N/01E-34G04	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
05N/02E-08B01	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Deionized water	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
blank	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table A6.--Pesticide concentrations reported by the Intergovernmental Resources Center

[µg/L, micrograms per liter]

Local well number	Date	Atrazine total (µg/L)	Simazine total (µg/L)	2,4-D total (µg/L)	2,4,5-TP Silvex total (µg/L)	Dinoseb total (µg/L)	Dalapon total (µg/L)	Glyphosate total (µg/L)
01N/03E-12L04	04-27-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
01N/04E-08K05	04-27-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
02N/01E-15Q01	05-03-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
02N/01E-23Q03	04-28-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
02N/01E-36B09	04-28-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
02N/02E-07A02	04-27-88	10	<5	<0.5	<0.15	<0.4	<0.5	<3
	04-27-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
	08-02-88	<3	--	--	--	--	--	--
02N/02E-27D02	04-28-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
02N/03E-06M01	04-26-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/01E-17P01	04-30-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
	04-30-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/01E-35B02	04-26-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/02E-03B01	04-25-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/02E-20H01	04-28-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/02E-35D02	04-26-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
03N/03E-03P01	04-26-88	<5	<5	<0.67	<0.15	<0.4	<0.5	<3
	07-20-88	--	--	<0.5	--	--	--	--
04N/01E-19F02	04-29-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
04N/01E-33B02	04-30-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
04N/02E-10N01	04-25-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
04N/03E-02D02	04-25-88	<5	<5	7.3	<0.15	<0.4	<0.5	<3
	07-20-88	--	--	<0.5	--	--	--	--
05N/01E-34G04	04-29-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
05N/02E-08B01	05-03-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
Deionized water blank	04-26-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
	04-29-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
	05-03-88	<5	<5	<0.5	<0.15	<0.4	<0.5	<3
	07-20-88	--	--	<0.5	--	--	--	--
	08-02-88	<3	--	--	--	--	--	--

APPENDIX B. Quality Assurance Review

The quality assurance plan for this study (G. L. Turney, U.S. Geological Survey, written commun., 1988) calls for quality-control procedures at all levels of data collection and analysis. Whereas many of the procedures address only methodology, some require the collection and analysis of quality-control samples. The resulting data are reviewed to determine the quality of the project data.

The quality of the water-quality data used in this study appears to be good by all measures. Errors of most standard and duplicate samples are within project criteria for most constituents. Exceptions occur when constituent concentrations are near detection limits, and small absolute errors result in large percentage errors. Concentrations in blanks, various internal sample checks, and comparisons of field and laboratory determinations were within acceptable limits for most constituents and samples.

The results of the quality-assurance analyses affected the interpretation of ground-water-quality data in a few cases. The presence of some organic compounds in blank samples casts some doubt on the presence of low levels of the same compounds in water samples. The presence of tetrachloroethene in only one sample of a duplicate pair raises questions about the presence of the compound in the ground water at the sampled well. The quality-assurance data did not affect any interpretations of inorganic data.

In the following sections, data from standard reference samples, sample duplicates, blanks, internal sample checks, and checks on field values are discussed. The data are included in the tables of Appendix A.

Standard Reference Samples

Standard reference samples of various concentrations for selected inorganic constituents were inserted as blind samples into the laboratory sample runs at the U.S. Geological Survey's National Water-Quality Laboratory (NWQL). Each standard sample was submitted several times to obtain enough data to be statistically meaningful. The results were summarized and are available through computer programs maintained by the U.S. Geological Survey's Branch of Quality Assurance (BQA). The summary provides the mean concentration determined by the NWQL for each standard during a given period, along with the standard deviation of the laboratory concentrations, coefficient of variation, and number of times the standard was submitted and analyzed. These data for standards submitted from April 15 to June 15, 1988, were used to assess the error in the analytical accuracy of samples collected from 76 Clark County wells during that period. The standards used in the assessment were only those that enclosed the range of the sample concentrations or, in cases when that was not possible, those that best represented the sample concentrations.

First, the standard deviation from the true standard concentration was determined for each standard using the following equation:

$$s_i = \sqrt{s^2_s + (\bar{u}_s - MPV_s)^2} \qquad (1)$$

s_i = standard deviation from the true standard concentration,

s_s = standard deviation from mean concentration determined by the NWQL,

$\bar{u}_s$ = mean concentration of standard as determined by the NWQL, and

MPV_s = most probable value of the standard. This is an estimate of the true standard concentration based on the average result from up to 150 independent laboratories.

Equation 2 was used to determine the coefficient of variation (CV_i) for the analysis of each standard:

$$CV_i = s_i/MPV_s \qquad (2)$$

Then the overall coefficient of variation for a particular constituent was determined by averaging the squares of the coefficients of variation for all of the standards that were in the range of concentrations found in Clark County. This average was weighted by the number of times each standard was analyzed in the period as follows:

$$CV_o = \sqrt{\frac{\sum_{i=1}^{m} (n_i-1)\ CV_i^2}{\Sigma(n_i-1)}} \qquad (3)$$

where

CV_o = overall coefficient of variation of all standards for a constituent,

n_i = number of times the standard was submitted and analyzed, and

m = number of standards.

The overall coefficient of variation usually overemphasizes standards at larger concentrations when the concentration ranges over several standards. This is because standards are submitted in approximately equal numbers over the entire concentration range, but the constituent concentrations in the ground-water samples are mostly in the smaller end of the range; only a small percentage of samples are in the larger end of the concentration range. In fact, in many cases the median ground-water concentration was smaller than the smallest standard, even though the sample concentration range covered several standards. The consequences of the unequal concentration distributions between standards and samples is minimal, though, because the coefficients of variation for the standards do not vary much with concentration.

The overall coefficient of variation was used to estimate the overall error of analysis of the standard reference samples for the constituent, at the 95-percent confidence level. The following equation was used:

$$E = (1.96\ CV_o) \times 100 \qquad (4)$$

where

E = overall error of analysis, in percent.

This error is also a representation of the average error in analytical accuracy of the samples from Clark County, and is shown in table B1 for each constituent. It is recognized that this error does include a degree of analytical precision. However, the accuracy and precision are difficult to separate in the given data and, in the interest of conservation, the error is considered to be entirely in the accuracy.

The average absolute standard deviations (S_o) for each constituent, in units based on concentration, is calculated using equation 5, and also shown in table B1.

$$S_o = \sqrt{\frac{\sum_{i=1}^{m}((n_i-1)s_i^2)}{\Sigma(n_i-1)}} \qquad (5)$$

The estimated errors for the cations and anions determined in this study are generally reasonable. Quality-assurance goals for this study called for a maximum error of 10 percent or less for cations, anions, and nutrients. The errors for calcium, magnesium, sodium, alkalinity, silica, and dissolved solids are in that range. The errors for sulfate, chloride, and nitrate are 22, 12, and 18 percent, respectively, and are probably representative, given the small concentrations. Likewise, errors of 43 to 160 percent for potassium, fluoride, and phosphorus are the result of the small concentrations that were close to the detection limit. At these low concentrations, acceptable small absolute errors (standard deviation) produce large-percentage errors. For example, an absolute error of 0.2 mg/L is a 20-percent error for a concentration of 1.0 mg/L, but is only a 2-percent error for a concentration of 10 mg/L.

Errors for metals range from 12 to 140 percent. In a few instances the error is within the goal of 20 percent. However, the generally high percent error associated with metals usually occurs because concentrations were at or near detection limits for all metals. Even though the percentages themselves are high at these low levels, the absolute errors are acceptable.

Internal surrogate standards were injected into each sample to be analyzed for concentrations of volatile organic compounds. The standards are used to determine percent recoveries, and those that are not detected within a certain percentage of the known concentrations (variable, dependent upon the compound) are identified by the NWQL. No samples were reported to have substandard volatile organic compound recoveries.

Table B1--Estimated error in analysis of inorganic constituents

[Concentrations in milligrams per liter unless otherwise noted. All are dissolved concentrates; µg/L, micrograms per liter]

Constituent	Number of standards	Number of times standards submitted	Median concentration in ground-water samples	Range of concentration in ground-water samples	Range of concentration of standards	Average absolute standard deviation of standards	Average[a] percent error in analysis
Calcium	5	41	17	0.57 - 52	14.3 - 71.5	1.0	6.3
Magnesium	4	35	7.3	.02 - 15	3.10 - 15.6	.44	7.9
Sodium	6	45	7.6	1.1 - 70	8.09 - 88.6	1.5	9.2
Potassium	9	56	1.8	.10 - 6.6	.17 - 4.92	.32	60
Alkalinity (lab)	9	58	83	4.0 - 202	38.9 - 179	2.5	5.3
Sulfate	3	31	1.6	<.20 - 29	13.7 - 45.9	2.3	22
Chloride	9	57	2.6	1.1 - 110	10.7 - 75.5	2.5	12
Fluoride	9	56	.20	.1 - 2.0	.06 - 1.4	.083	160
Silica	9	57	47	8.4 - 68	3.43 - 13.6	.33	8.2
Dissolved solids (analyzed)	4	35	132	12 - 245	102 - 314	6.1	6.0
Nitrate	3	55	.16	<.10 - 6.7	1.00 - 3.00	.16	18
Phosphorous	2	42	.07	<.01 - .33	.10 - .80	.059	43
Aluminum (µg/L)	2	6	<10	<10 - 50	54.3 - 60.8	9.3	33
Iron (µg/L)	4	44	5	<3 - 7,700	67.0 - 119	10	30
Manganese (µg/L)	4	44	2	<1 - 690	20.4 - 56.3	3.5	32
Antimony (µg/L)	2	6	<1	<1 - 13	7.24 - 8.10	1.6	42
Arsenic (µg/L)	2	7	1	<1 - 4	3.89 - 4.35	2.8	140
Barium (µg/L)	2	17	7	<2 - 30	56.8 - 63.0	.67	2.2
Boron (µg/L)	2	13	<10	<10 - 40	16.6 - 95.3	4.8	38
Cadmium (µg/L)	2	17	<1	<1 - <1	10.5 - 10.9	2.7	49
Chromium (µg/L)	2	7	<1	<1 - 3	10.9 - 12.2	1.9	33
Copper (µg/L)	4	18	2	<1 - 18	11.3 - 20.9	2.3	30
Lead (µg/L)	4	18	<5	<5 - <5	3.15 - 11.3	3.3	85
Mercury (µg/L)	1	6	<.1	<.1 - .1	.24	.14	114
Molybdenum (µg/L)	2	7	<1	<1 - 3	8.78 - 9.83	2.0	44
Nickel	4	22	1	<1 - 4	3.75 - 11.4	3.3	89
Selenium (µg/L)	1	6	<1	<1 - 1	5.5	.55	20
Silver (µg/L)	2	27	<1	<1 - 1	5.00 - 7.00	1.8	66
Zinc (µg/L)	4	43	10	<3 - 170	94.5 - 153	6.0	12

[a] At 95-percent confidence level. Computed using equations described in the text and data supplied by the U.S. Geological Survey's Branch of Quality Assurance. Error criterion is 10 percent for cations, anions, silica, dissolved solids, and nutrients. Error criterion is 20 percent for metals and trace elements.

Duplicate Samples

Duplicate pairs of samples were collected for all types of analyses performed. Precision criteria were a 10-percent maximum difference for turbidity, cations, anions, silica, dissolved solids, and nutrients, and a 20-percent maximum difference for trace elements, radiochemical constituents, and organic compounds. A difference for each pair was computed as a percentage of the average concentration for the pair. The average difference of all pairs and the number of pairs exceeding the difference criteria are listed for each constituent in table B2. Constituents that are calculated from concentrations of other constituents are not shown.

For most constituents, the average percentage difference is well within the criterion, and rarely does even a single pair exceed the criterion. Exceptions are turbidity, sulfate, fluoride, phosphorus, copper, gross alpha, gross beta, 1,1,1-trichloroethane, and tetrachloroethene, where small absolute differences occurred because concentrations were at or near the detection limit. These resulted in large-percentage errors, but are acceptable because of the small concentrations. For radon 222, a pair with concentrations of 280 and 470 pCi/L (picoCuries per liter) is well above the detection limit of 80 pCi/L, and may reflect a sampling or analytical problem. However, the overall difference for radon is 12.5 percent (including this pair) and the problem is probably isolated.

The only duplicate pair affecting data interpretations is from well 03N/01E-17P01, where the pairs had tetrachloroethene concentrations of <0.2 and 1.3 μg/L. This causes some doubt as to whether the compound was actually present; this is addressed in the text (p. 32).

Blanks

Blanks were prepared from deionized water in the same manner as water samples and sent to the NWQL for analysis. Although no criteria were set for constituent concentrations in blanks, the significance of any constituent present in a blank is based on how close the constituent concentration is to the detection limit and how small it is compared to the median sample concentration. Also important is the number of times the constituent was detected in blank samples. These data are presented in table B3, and it is apparent that when compared with these criteria, concentrations in blanks were insignificant for all constituents except four organic compounds. Concentrations of dichloromethane, tetrachloroethene, toluene, and bis(2-ethylhexyl)-phthalate in at least one blank sample exceeded median concentrations in ground-water samples. Potential sources exist for all of these compounds except tetrachloroethene. Dichloromethane is a common laboratory solvent, toluene may originate from the laboratory or from the column used to prepare the deionized water, and bis(2-ethylhexyl)phthalate could have leached from the plastic containers in which the deionized water was stored for field transport. These sources were considered when interpreting the data.

Table B2.--Average differences in constituent values and concentrations determined for duplicate samples

Constituent	Number of duplicate pairs	Average differ- ence, in percent	Number[a] of pairs exceeding difference criteria
Turbidity	6	22	3
Total coliform	8	2	--
Fecal coliform	8	0	--
Fecal streptococci	8	20	--
Calcium	6	0	0
Magnesium	6	.8	0
Sodium	6	2.1	0
Potassium	6	2.4	0
Bicarbonate	6	.7	0
Carbonate	6	0	0
Alkalinity - Field	6	.7	0
Alkalinity - Lab	6	.3	0
Sulfate	6	3.7	1
Chloride	6	3.5	0
Fluoride	6	10.4	2
Silica	6	.2	0
Dissolved solids	6	2.3	0
Nitrate	6	1.1	0
Phosphorus	6	5.3	1
Aluminum	6	0	0
Iron	6	1.8	0
Manganese	6	0	0
Antimony	2	0	0
Arsenic	2	0	0
Barium	2	0	0
Beryllium	2	0	0
Boron	2	0	0
Cadmium	2	0	0
Chromium	2	0	0
Copper	2	93	2
Lead	2	0	0
Mercury	2	0	0
Molybdenum	2	0	0
Nickel	2	0	0
Selenium	2	0	0
Silver	2	0	0
Thallium	2	0	0
Vanadium	2	0	0
Zinc	2	0	0
Cyanide	2	0	0
Gross Alpha	2	58	2
Gross Beta	2	24	2

Table B2.--Average differences in constituent values and concentrations determined for duplicate samples--Continued

Constituent	Number of duplicate pairs	Average differ- ence, in percent	Number[a] of pairs exceeding difference criteria
Radium-226	2	0	0
Radium-228	2	0	0
Radon-222	6	12.5	1
Uranium	2	4.4	0
1,1,1-trichloroethane	2	33	1
Trichloroethene	2	0	0
Tetrachloroethene	2	106	2
All other organics[b]	2	0	0

[a] Difference criterion is 10 percent for turbidity, cations, anions, silica, dissolved solids, and nutrients. Percent-difference criterion is 20 percent for all trace elements, radiochemicals, and organic compounds. No percent-difference criterion was established for bacteria.

[b] Organic compounds other than those shown were not detected in any of the duplicate samples, therefore, all differences for these other compounds are zero.

Table B3.--Summary of constituent values and concentrations determined for blank samples

[Concentrations in milligrams per liter unless otherwise noted. NTU, nephelometric turbidity units; col/100 mL, colonies per 100 milliliters; µg/L, micrograms per liter; pCi/L, picocuries per liter]

Constituent	Number of blanks	Detection limit	Maximum blank concentration	Median sample concentration	Number of blanks equal to or exceeding detection limit
Turbidity (NTU)	3	0.1	0.2	0.3	1
Total coliform[a] (col/100 mL)	39	1	14	<1	1
Fecal streptococci (col/100 mL)	30	1	2	<1	3
Calcium	5	.02	.06	17	1
Magnesium	5	.01	.01	7.3	1
Sodium	5	.2	<.2	7.6	0
Potassium	5	.1	.1	1.8	5
Alkalinity - Lab	5	1.0	2.0	83	5
Sulfate	5	.2	<.2	1.6	0
Chloride	5	.1	.4	2.6	5
Fluoride	5	.1	.2	.20	5
Silica	5	.01	.02	47	3
Dissolved solids	5	1	1	132	1
Nitrate	5	.1	<.1	.16	0
Phosphorus	5	.01	.03	.07	3
Aluminum (µg/L)	5	10	<10	<10	0
Iron (µg/L)	5	3	<3	5	0
Manganese (µg/L)	5	1	1	2	1
Antimony (µg/L)	1	1	<1	<1	0
Arsenic (µg/L)	1	1	<1	1	0
Barium (µg/L)	1	2	<2	7	0
Beryllium (µg/L)	1	.5	<.5	<.5	0
Boron (µg/L)	1	10	<10	<10	0
Cadmium (µg/L)	1	1	<1	<1	0
Chromium (µg/L)	1	1	<1	<1	0
Copper (µg/L)	1	1	1	2	1
Lead (µg/L)	1	5	<5	<5	0
Mercury (µg/L)	1	.1	<.1	<.1	0
Molybdenum (µg/L)	1	1	<1	<1	0
Nickel (µg/L)	1	1	<1	1	0
Selenium (µg/L)	1	1	<1	<1	0
Silver (µg/L)	1	1	<1	<1	0
Thallium (µg/L)	1	1	<1	<1	0
Vanadium (µg/L)	1	1	<1	10	0
Zinc (µg/L)	1	3	<3	10	0
Cyanide	1	.01	<.01	<.01	0
Gross alpha (µg/L as Uranium)	1	.4	<.4	<.4	0
Gross beta (pCi/L as Cesium-137)	1	.4	<.4	2.3	0
Radium-226 (pCi/L)	1	.02	<.02	.02	0
Radium-228 (pCi/L)	1	1.0	<1.0	<1.0	0
Radon-222 (pCi/L)	5	80	<80	315	0

Table B3.--Summary of constituent values and concentrations determined for blank samples --Continued

Constituent	Number of blanks	Detection limit	Maximum blank concentration	Median sample concentration	Number of blanks equal to or exceeding detection limit
Uranium (μg/L)	1	1	<1	<1	0
Dichloromethane (μg/L)	2	.2	1.1	<.2	1
Tetrachlorethene (μg/L)	2	.2	.3	<.2	1
Toluene (μg/L)	2	.2	.4	<.2	1
bis(2-ethylhexyl)phthalate (μg/L)	2	5.0	15	<5.0	1
All other organics[b]	2	(c)	(c)	(c) 0	

[a] Total coliform blanks also served as blanks for fecal coliform.

[b] Organic compounds other than those shown were not detected in the blanks.

[c] Detection limits vary from 0.2 to 30 μg/L, depending upon the compound. In all cases the maximum blank concentration and the median sample concentrations are less than the detection limit.

Internal Sample Checks

Various sums, differences, and ratios based on aquatic chemistry principles were computed for each sample. These computations check the consistency between constituent concentrations in a sample and provide a gross check in the accuracy and completeness of the analysis. Two of the most useful computations are the cation-anion balance and the calculated dissolved-solids concentration, which are defined in the following paragraphs.

The cation-anion balance is calculated as a percent difference, using the following equation:

$$\frac{\Sigma \text{ cations} - \Sigma \text{ anions}}{\Sigma \text{ cations} + \Sigma \text{ anions}} \qquad (6)$$

where

Σ cations = the sum of the concentrations of cations, in milliequivalents, and

Σ anions = the sum of the concentrations of anions, in milliequivalents.

Ideally, this value is zero, but nonzero values occur when a cation or anion concentration is in error, or when an ion present in large concentrations (often a metal) is not analyzed. The acceptable percentage difference varies with the total sum of cations and anions, as shown in figure B1. For the samples collected in Clark County, results of six analyses exceeded the allowable percentage difference. However, in five of these analyses, the field and laboratory alkalinity concentrations differed by 5 percent or more (discussed in the next section). The cation-anion balance was initially done using the field value, so in these five analyses the laboratory value was substituted into the balance equation, and an acceptable percentage difference was obtained for four of them. This left two analyses of the entire data set that had unacceptable cation-anion balances, but individual concentrations were reasonable, and the data were allowed to stand.

Calculated solids is the dissolved-solids concentration determined by summing the concentrations of cations, anions, silica, and other major dissolved constituents. This value is theoretically equal to the dissolved-solids concentration determined analytically. Differences usually are due to errors in analyses of the various cations or anions (which can be verified by the cation-anion balance), or errors in the analyzed dissolved-solids concentration. For this study, 12 of 76 samples had a difference of 10 percent or greater between the calculated and analyzed dissolved solids. Of these, eight were in the eastern part of the county. Although determining the exact cause of the difference is virtually impossible, the fact that there is some geographic distribution suggests that something unique to ground water from that area could be a factor.

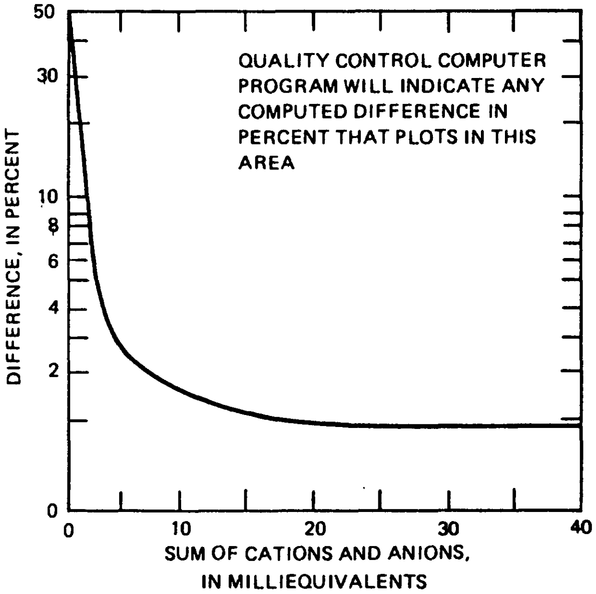

FIGURE B1.--Cation and anion percent-difference curve.

Checks on Field Values

The primary controls on field values of pH, specific conductance, dissolved oxygen, and temperature are proper instrument calibration and field procedures. However, pH and specific conductance are also determined in the laboratory. Laboratory and field specific conductances differed by more than 5 percent for only 9 of 76 samples and exceeded 10 percent for only 3 of these 9 samples. Field and laboratory pH differed by more than 0.2 units for 20 of 76 samples, but only 6 of these differed by more than 0.5 units. The maximum difference was 0.8 unit. Because pH and specific conductance values can change during the time between the field and laboratory determinations, these comparisons must be considered approximations at best, but the good agreement generally serves to confirm the field values.

Field determinations of bicarbonate and carbonate concentrations were checked by calculating alkalinities from them and comparing the results with laboratory-determined alkalinities. Field and laboratory alkalinities differed by more than 5 percent for 12 of 76 samples, and differed by more than 10 percent for 5 of these 12. However, when the cation-anion balance (discussed previously) was used to determine which was a better value, in only two instances did the field value provide the better balance, and the difference was negligible. These results are consistent with qualitative observations for other ground-water studies in western Washington (N. P. Dion, U.S. Geological Survey, oral commun., 1989). The results suggest that for these waters, differences in field and laboratory alkalinities are usually insignificant, and that where differences occur, the laboratory value will probably be the better of the two. This raises doubt about the need to do alkalinity determinations in the field. These alkalinity comparisons could be applicable only to ground-water samples with similar chemical composition and from similar geologic settings to those found in Clark County.

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